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Academy Editors

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VOLUME XXXIV
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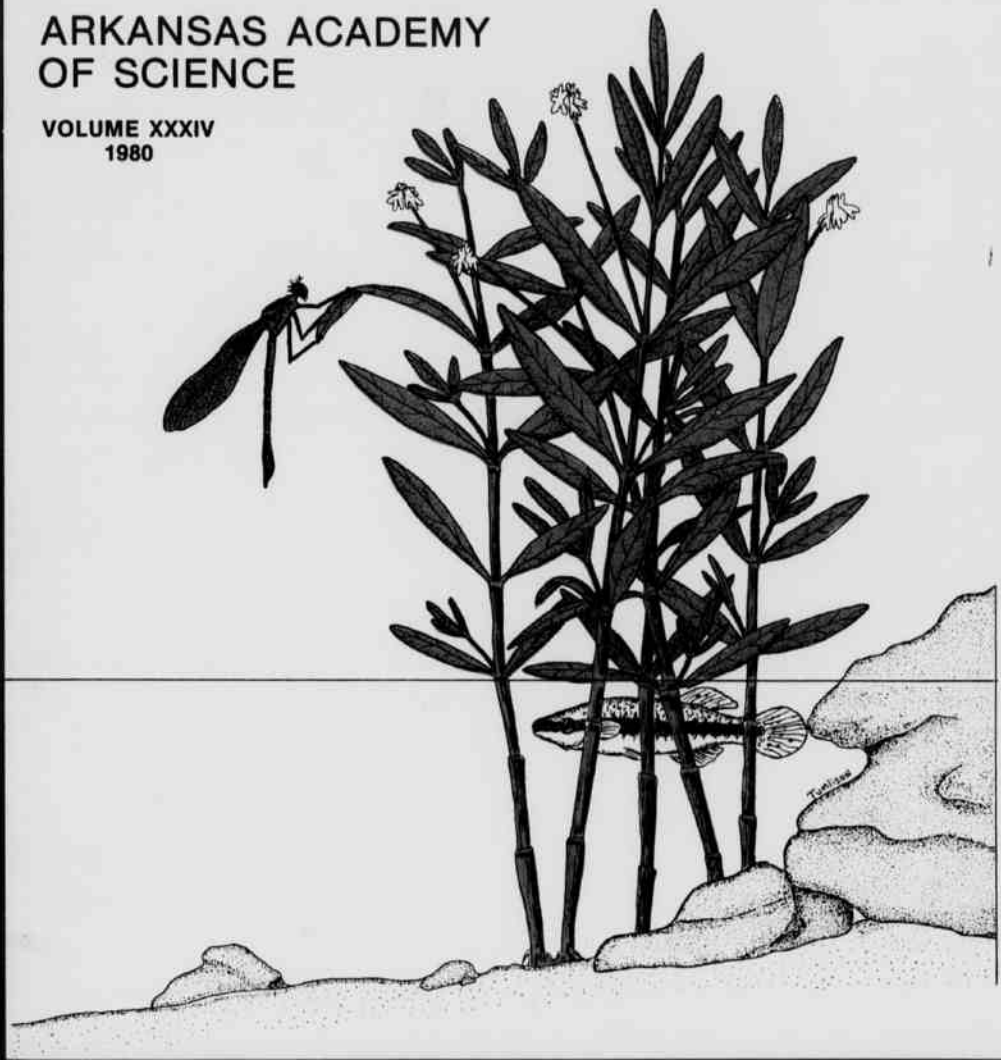

ARKANSAS ACADEMY OF SCIENCE
BOX 837
STATE UNIVERSITY, ARKANSAS 72467

LIBRARY RATE

Arkansas Academy of Science, Box 837, Arkansas State University
State University, Arkansas 72467

PAST PRESIDENTS OF THE ARKANSAS ACADEMY OF SCIENCE

Charles Bookover, 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. Wills, 1941-42
L. B. Roberts, 1943-44
Jeff Banks, 1945
H. L. Winburn, 1946-47
E. A. Provine, 1948
G. V. Robinette, 1949
R. H. 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

INSTITUTIONAL MEMBERS

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

ARKANSAS STATE UNIVERSITY, State University
ARKANSAS TECH UNIVERSITY, Russellville
COLLEGE OF THE OZARKS, Clarksville
HENDERSON STATE UNIVERSITY, Arkadelphia
HENDRIX COLLEGE, Conway
JOHN BROWN UNIVERSITY, Siloam Springs
OUACHITA BAPTIST UNIVERSITY, Arkadelphia
SOUTHERN ARKANSAS UNIVERSITY, Magnolia
UNIVERSITY OF ARKANSAS AT FAYETTEVILLE
UNIVERSITY OF ARKANSAS AT LITTLE ROCK
UNIVERSITY OF ARKANSAS AT MONTICELLO
UNIVERSITY OF ARKANSAS AT PINE BLUFF
UNIVERSITY OF CENTRAL ARKANSAS, Conway

EDITORIAL STAFF

IN MEMORY

Clarence Bruce Sinclair, 1924-1980

Clare Sinclair died on June 5, 1980, after a four year illness. For the past sixteen years he had been a member of the faculty of the University of Arkansas at Little Rock including five years with Little Rock University and the remainder with the University of Arkansas at Little Rock. He served with distinction as Dean of the Division of Life Sciences, Associate Dean of the College of Sciences, and Professor of Biology. He received his bachelor's and master's degrees from the University of Kansas City and the doctorate from the University of Missouri, his home state. Before coming to Arkansas, he taught at National College and the University of Missouri.

He was held in highest regard by faculty, staff and students for his professional achievements and personal attributes. His research activity resulted in a number of publications and reports in the areas of ecological surveys, plant morphology and plant taxonomy. He was a dedicated and active participant in the Arkansas Academy of Science, and he served the Academy in a variety of capacities. He will be missed by his friends, colleagues, and the Academy.

James H. Fribourgh
University of Arkansas at Little Rock

ARKANSAS ACADEMY OF SCIENCE

Volume XXXIV 1980

Proceedings

E. Leon Richards
President

Henry W. Robison	David M. Chittenden	William L. Evans	Robert T. Kirkwood
President-Elect	Secretary	Treasurer	Historian

Secretary's Report

MINUTES OF THE SIXTY-FOURTH ANNUAL MEETING—28-29 March 1980

FIRST BUSINESS MEETING

Dr. E. Leon Richards, President, opened the meeting by introducing Dr. Eugene Smith, Acting President of Arkansas State University, who welcomed the members.

President Richards called for a volunteer for Editor of the Newsletter and then recognized Dr. William Evans for the Treasurer's Report. Evans stated that financial statements were available. He then discussed the financial statement, and gave a report on income and disbursements. The financial statement and summary of income and disbursements are shown below.

Financial Statement

March 15, 1980

Checking Acct. Statement, Mar. 31, 1979		$1,447.35
Outstanding Check (491)		100.94
Checking Acct., Cash Available Mar 31, 1979		$1,346.41
Heritage S & L Certificate of Deposit		1,306.96
Heritage S & L Passbook Acct. 7679		2,124.14
Total Funds Available, Mar. 31, 1979		$4,777.51
INCOME (Apr. 1, 1979 through Mar. 15, 1980)		
1. Individual Memberships		$1,374.00
a. Sustaining Dues	$ 310.00	
b. Regular Dues	1,024.00	
c. Associate Dues	40.00	
2. Institutional Dues		700.00
3. Subscriptions to the PROCEEDINGS		913.67
4. Page Charges		834.03
5. BIOTA Donations		21.25
6. AAAS for Grants		99.00
7. Exhibitor's Fees, Hendrix College		200.00
8. Interest on Reserve Funds		109.75
a. Certificate (6.5%) Conv. 2/12/80	75.62	
b. Passbook (5.25%)	34.13	
Total Income		$4,251.70
DISBURSEMENTS (Apr. 1, 1979 through Mar. 15, 1980)		
1. Meeting Expenses, Hendrix (493)		$ 200.00
2. Operating Expenses		96.00
a. Carson, Typing (497)	6.00	
b. UAF, Data Labels (498)	19.67	
c. UAF, Receipt Books (500)	5.43	
d. Nat. Assn. Acad. Sci. Dues (502)	25.20	
e. Postmaster, Stamps (505)	7.50	
f. UAF, Printing (506)	1.45	
g. Chem. Dept. ASU, Records Tr. (507)	23.25	
h. Postmaster, Box Rent (517)	7.50	
3. BIOTA, UAF for Printing (499)		42.10
4. Awards		$ 431.84
a. Day-Timers, Certificates, (492)	$ 71.84	
b. Thiele, Sci. Talent (494)	25.00	
c. Nix, Sci. Talent (495)	20.00	
d. Trott, Sci. Talent (496)	15.00	
e. Ark. Sci. Fair Assn. (503)	100.00	
f. Ark. Jr. Acad. Sci. (510)	200.00	
5. Publishing & Distribution, PROCEEDINGS		3,559.21
a. Phillips Litho. Printing (501)	3,130.41	
b. Gilmour, Postage (504)	17.97	
c. R. Heidt, Ed. Asst. (508)	118.80	
d. R. Heidt, Ed. Asst. (513)	231.00	
e. Dept. Fin. & Adm., WH Tax (514)	3.20	
f. G. Heidt, Postage (515)	3.19	
g. Chittenden, Postage (516)	15.04	
h. R. Heidt, Ed. Asst. (519)	39.60	
6. Publication & Distribution, NEWSLETTER		81.92
a. Postmaster, Shipping (509)	9.77	
b. Robison, Postage (511)	18.75	
c. UAF, Printing (512)	53.40	
Total Disbursements		$4,411.07

SUMMARY

Beginning Balance, Checking and Reserve	$4,777.51
Total Income	+4,251.70
Total Expenditures	-4,411.07
Funds on Hand, March 15, 1980	$4,618.14

ACCOUNTS

Checking Acct., McIlroy Bank, March 15, 1980	$2,577.29
Heritage S & L Certificates (2½ yr. 10.65%)	1,000.00
Heritage S & L Passbook (5.25%)	1,040.85
Funds on Hand, March 15, 1980	$4,618.14
Outstanding Bills, March 15, 1980	
1. Phillips Litho, Inc., Printing PROCEEDINGS	$3,399.87
2. G. Heidt, Travel	121.68
Total Obligations	$3,521.55

Respectfully submitted,

William L. Evans
Treasurer

March 28, 1980
Meeting at Arkansas State
University

President Richards recognized Dr. Jewel Moore, chairman of the Nominating Committee, who gave the following report on candidates for the office of President-elect.

The Nominating Committee consists of Dr. Dan England and Dr. James Wickliff and we are pleased to present two names for your consideration.
They are: John K. Beadles - ASU
John Stuckey - Hendrix
Voting will take place at the Second Business Meeting.

Dr. Art Johnson, chairman of the Constitutional Revision Committee, presented the following proposed changes to the Constitution and Bylaws.

1. Article 3, Section 2 of the Constitution shall be changed to read:

There shall be two classes of membership in the Academy: Members (Regular and Sustaining) and Institutional Members.

2. Article 3, Section 3 of the Constitution shall be deleted.

3. Article 4 of the Constitution shall be changed to read:

> The officers of the Academy shall be a President, a President-elect, a Vice-President, a Secretary, a Treasurer, a Historian, and an Editor who shall perform the duties usually pertaining to their respective offices. All officers of the Academy except the President and President-elect shall be chosen by ballot by the membership-at-large in the annual meeting and hold office for one year, except the Secretary, Treasurer, Historian and Editor who shall hold office for five years. The office of President shall be filled by the preceding year's President-elect. The office of President-elect shall be filled by the preceding year's Vice-President. These officers, the Advisor of the Collegiate Academy and other members designated by the President shall constitute the Executive Committee of the organization. The President of the Collegiate Academy or his/her representative shall be an ex-officio non-voting member of the Executive Committee.

4. Section 10 of the Bylaws shall be changed to read:

> Dues for all members (Sustaining, Regular, Institutional) 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 that in which the change has been approved.

The recommended dates for activation of the above amendments are:

Amendments 1, 2, and 4:	29 March, 1980
Amendment 3:	the date of the initial meeting of the Nominating Committee for 1981.

Voting on the amendments will take place at the Second Business Meeting.

Mr. Tom Palko reported on the Junior Science and Humanities Symposium as follows.

> The 14th Arkansas Science and Humanities Symposium was held at Arkansas Tech University on 20-22 March 1980. Seventeen papers, out of seventy-two submitted, were read and five were chosen for presentation at the national meeting at the University of South Carolina-Columbia in May. In addition there were speeches and a tour of Arkansas Nuclear One.

Jewel Moore, chairman of the Committee on Certification Requirements presented the following resolution for consideration by the Academy.

> Be it resolved that: For certification in a particular field, only those courses be counted which would apply toward a major in that field, for a total of twenty-four (24) hours in that field.

The adoption of this resolution will be moved at the Second Business Meeting.

SECOND BUSINESS MEETING

President Richards called the Second Business Meeting to order. The election of President-elect was conducted by ballot. John K. Beadles was elected.

President Richards recognized Dr. Gary Heidt, Editor, who gave the following report.

> Because of the rapidly increasing costs in producing the PROCEEDINGS, the Editorial Board and Executive Committee of the Academy have decided to implement a $15.00 charge per printed page, or part thereof. This charge will be implemented with the issue this year, Volume 34. The old policy of recovering full cost after two pages will, of course, be dropped. In addition, notes which fill only half of two pages or less will only be charged the equivalent of one page. While these changes are disagreeable at best, they were not imposed arbitrarily and do not seem out of line with other publications including Academies of Science. I would also like to thank the Associate Editors for another fine job.

Dr. Heidt then made the following motion.

> I move that the Arkansas Academy of Science appropriate $450.00 for editorial assistance to prepare Volume 34 of the Proceedings.

The motion was seconded and passed.

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

> I move that the minutes of the 63rd Annual Meeting published in the 33rd Proceedings of the Arkansas Academy of Science be approved as written.

The motion was seconded and passed.

Dr. William Evans, Treasurer, made the following motion.

> I move the acceptance and approval of the Treasurer's financial statement and report for the period 1 April, 1979 through 15 March, 1980, as submitted to the membership and presented at the First Business Meeting.

The motion was seconded.

Dr. Henry Robison, chairman of the Audit Committee, made the following report.

> James Wickliff, Rick McDaniel and myself audited the books. We found the financial records to be in order and Dr. Bill Evans should be commended for his diligent work and gracious assistance to this committee.

The motion by Dr. Evans was passed.

Professor Robert Kirkwood, Historian, reported that he will update the list of meetings and that the 1980 PROCEEDINGS will carry an up-to-date list of past officers.

President Richards recognized Dr. Art Johnson, sponsor of the Collegiate Academy, who reported that the following officers of the Collegiate Academy had been elected:

President: Jane Spradley - Hendrix
President-elect: James Briggs - College of the Ozarks
Secretary: David Ratcliff - Hendrix

Dr. Robison then made the following motion.

> I move that the Senior Academy approve up to $200.00 to cover expenses and operations of the Collegiate Academy for the coming year.

The motion was seconded and passed.

President Richards gave the following report on the Junior Academy.

Five Junior Academy members attended the AAAS meeting in San Francisco where four presented papers at the Junior Academy Section.

Three members of the Junior Academy have been selected to receive grants totalling $100.00.

Dr. Evans moved that $200.00 be appropriated to support the Junior Academy in the coming year. The motion was seconded and passed.

President Richards recognized Dr. Leo Paulissen on the Arkansas (Westinghouse) Science Talent Search.

Arkansas had two honorees at the national meeting. David Wickliff won a top award. Susan Newland was the other honoree.

It was announced that the 1982 meeting of the Academy will be held at Henderson State University. President Richards reminded the members that the 1981 meeting will be held at UALR. There is a possibility that the meeting will be held at the LR Convention Center.

The passage of the resolution proposed by the Committee on Certification Requirements was moved. The motion was seconded and passed.

Dr. Art Johnson explained the proposed amendments to the Constitution and Bylaws. The acceptance of these amendments was moved. The motion was seconded and passed.

Dr. Sealander, chairman of the Resolutions Committee, moved the adoption of the following resolution.

Be it resolved:

By the members of the Academy in session on 29 March at Arkansas State University in Jonesboro that the Academy wishes to express its sincere thanks and appreciation to Dr. Eugene Smith, Acting President of Arkansas State University, and to the faculty and staff of Arkansas State University for the use of their facilities and their warm hospitality.

Furthermore, the Academy extends its congratulations to the local Arrangements Committee, Dr. Van Rick McDaniel, chairman, and to the Chairpersons of the Academy sections: Alex Nisbet, Hal McCloud, Don Culwell, John K. Beadles, Neal Buffaloe, Walter Manger, Robert Watson, Dennis Baeyens, Albert Ogden, Chris Spatz, and John E. Pauly.

The Academy also wishes to express its thanks to Edward L. Richards, President of the Academy, David Chittenden, Secretary, William L. Evans, Treasurer, Gary Heidt, Editor, Robert Kirkwood, Historian, and Henry Robison, Editor of the Newsletter, for the excellent manner in which they have discharged their duties during the past year.

The Academy also expresses its congratulations to the outstanding work of the organizations sponsored by the Academy and its appreciation to the sponsors and directors of these groups: Marie Arthur, Director of the Junior Academy of Science; Tom Palko, Director, Junior Science and Humanities Symposium; Edmund Wilson, Sponsor, Collegiate Academy of Science; Carl Rutledge, Director, State Science Fair; Leo Paulissen, Science Talent Search and to Wayne Everett, Coordinator and Liason Officer for all sponsored activities.

The Academy also expresses its thanks to the following exhibitors: Micro-Tech Instruments, Inc.; and Curtin-Matheson Scientific, Inc., and American Optical.

The motion was seconded and passed.

President Richards recognized Gwen Barber who announced the formation of the Arkansas Native Plant Society and urged Academy members to become charter members of the Society.

President Richards announced that Rodney Harris has been named Outstanding Biology Teacher in Arkansas for 1980.

Dr. Leo Paulissen requested that checklists be submitted to the Arkansas Biota Survey when they reach 90% of completion. Copies of additions to the Survey are available.

Dr. Evans moved that the Executive Committee recommendation that dues be raised to $10.00 (Regular) and $12.00 (Sustaining), effective January 1, 1981, be approved by the membership. The motion was seconded and passed.

It was moved that the Academy appropriate $100.00 to the Arkansas Science Fair for the coming year. The motion was seconded and passed.

The formation of a Universities of Arkansas Press was discussed.

President Richards made his farewell remarks. Before taking office, Dr. Robison moved that $100.00 be appropriated for the Newsletter for the coming year. The motion was seconded and passed. It was announced that Dr. Rick McDaniel will become the Editor of the Newsletter.

Dr. Richards turned the gavel over to Dr. Robison. President Robison appointed the following to the Nominating Committee: Neal Buffaloe, chairman, Rick McDaniel, and John Bridgman.

President Robison adjourned the Second Business Meeting.

Respectfully submitted,

David M. Chittenden
Secretary

PROGRAM
Arkansas Academy of Science

Sixty-Fourth Annual Meeting

ARKANSAS STATE UNIVERSITY
State University, Arkansas

Meeting concurrently with sessions of:

The Collegiate Academy of Science

Friday, 28 March

SENIOR AND COLLEGIATE ACADEMIES -- Registration

SENIOR ACADEMY -- Executive Board Meeting

COLLEGIATE BUSINESS MEETING I

SENIOR ACADEMY -- First General Business Meeting

WESTINGHOUSE SCIENCE TALENT SEARCH AWARDS

Lunch

SENIOR AND COLLEGIATE ACADEMIES -- Registration

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

Chemistry
Mathematics and Physics
Biology I -- Botany
Aquatic Environment I
Science Education
Geology

SENIOR AND COLLEGIATE ACADEMIES -- Banquet
Speaker: Senator Dale Bumpers

Saturday, 29 March

SENIOR AND COLLEGIATE ACADEMIES -- Registration

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

Biology II -- Invertebrate Zoology
Biology III -- Vertebrate Zoology
Aquatic Environment II
Hydrogeology
Biomedical Science

SENIOR ACADEMY -- Second General Business Meeting

SECTION PROGRAMS

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

CHEMISTRY

Section Chairman: Alex Nisbet

*SYNTHESIS OF N-SUBSTITUTED ANALOGS OF ACYCLIC NARCOTIC ANALGESICS AS NARCOTIC ANTAGONISTS.
J. B. Richardson, P. K. Raible, D. L. Greene, and D. L. Lattin, Dept. of Biopharmaceutical Sciences, College of Pharmacy, University of Arkansas Medical Sciences Campus, Little Rock, Arkansas 72205.

*SYNTHESIS OF PENTAPEPTIDES AS MORPHINE AGONISTS AND ANTAGONISTS.
K. Lee Robinson, Lyle Van Arsdale, and A. Nelson Voldeng, College of Pharmacy, University of Arkansas Medical Sciences Campus, Little Rock, Arkansas 72205.

*THE CRYSTAL AND MOLECULAR STRUCTURE OF TRANS-TRANS-μ-CHLORO-μ-PYRAZOLATODICHLORO-BIS-(ETHYLENE) DIPLATINUM (II), $C1(C_2H_4)$ $PT(\mu\text{-}C1)$ $(\mu\text{-}C_3N_2H_3)$ $PT(C_2H_4)$ C1.
A. W. Cordes, W. C. Deese, and D. A. Johnson, Dept. of Chemistry, University of Arkansas, Fayetteville, Arkansas 72701.

THE HEMORRHAGIC FRACTION IV OF TIMBER RATTLESNAKE VENOM.
David J. Civello, Lan H. Duong, and Collis R. Geren, Department of Chemistry, University of Arkansas, Fayetteville, Arkansas 72701.

THE SYSTEMIC EFFECTOR FROM BROWN RECLUSE SPIDER VENOM.
James L. Babcock and Collis R. Geren, Department of Chemistry, University of Arkansas, Fayetteville, Arkansas 72701.

PARTIAL PURIFICATION AND CHARACTERIZATION OF A HEMORRHAGIN FROM TIMBER RATTLESNAKE VENOM.
Ellen Farr Young and Collis R. Geren, Department of Chemistry, University of Arkansas, Fayetteville, Arkansas 72701.

IMPLEMENTATION OF THE NASA CHEMICAL EQUILIBRIUM PROGRAM AT ARKANSAS STATE UNIVERSITY.
J. Edward Bennett, Paul D. Gwinup, and Wade Martin Simpson, Department of Chemistry, Arkansas State University, State University, Arkansas 72467.

REACTIONS OF HEX-1-ENOPYRAN-3—ULOSES WITH SOME ORGANOMETALLIC REAGENTS.
Thomas E. Goodwin, Byron Curtner, Jim Loomis, and Newton Seitzinger, Department of Chemistry, Hendrix College, Conway, Arkansas 72032.

A GLYCOPROTEIN PROTEINASE IN *AGKISTRODON BILINEATUS* VENOM.
John D. Ruff, Bob D. Johnson, and Dewey H. Sifford, Departments of Biology and Chemistry, Arkansas State University, State University, Arkansas 72467.

ISOLATION OF PHOSPHOLIPASE A_1 FROM *AGKISTRODON BILINEATUS* VENOM.
Karl H. Landberg, Bob D. Johnson, and Dewey H. Sifford, Departments of Biology and Chemistry, Arkansas State University, State University, Arkansas 72467.

CHARACTERIZATION OF COPPERHEAD VENOMS.
Jeffrey B. Moran and Collis R. Geren, Department of Chemistry, University of Arkansas, Fayetteville, Arkansas 72701.

AN EXPERIMENTAL SYSTEM FOR THE DETERMINATION OF VAPORIZATION KINETICS AND THERMODYNAMICS AT TEMPERATURES TO 3300°K.
J. Edward Bennett and Paul D. Gwinup, Department of Chemistry, Arkansas State University, State University, Arkansas 72467.

KETONE SYNTHESIS VIA THE SYNTHETIC EQUIVALENT OF A γ-ALKYLATION OF 1-ARYL-2-METHYL-2-PROPEN-1-OLS.
Thomas E. Goodwin and David Ratcliff, Department of Chemistry, Hendrix College, Conway, Arkansas 72032.

PHYSICS AND MATH

Section Chairman: Hal McCloud

THE F+ CENTER IN ZINC SULFIDE.
W. F. Wei, Dept. of Mathematics and Physics, Arkansas State University.

USE OF A POCKET CALCULATOR FOR REALTIME DATE PROCESSING.
Jeffrey O. Cohen and Hal E. McCloud, Dept. of Mathematics and Physics, Arkansas State University.

BOTANY AND AGRICULTURE

Section Chairman: Don Culwell

NOTES ON THE FUNGUS FLORA (GASTEROMYCETES) OF NORTHWEST ARKANSAS.
George T. Johnson, Department of Botany and Bacteriology, University of Arkansas at Fayetteville.

POLLEN STUDIES IN THE CESTREAE AND SALPIGLOSSIDEAE (SOLANACEAE).
Johnnie L. Gentry, Jr., University of Arkansas Museum at Fayetteville.

REMNANT PRAIRIE IN FAULKNER, COUNTY, ARKANSAS.
Donald E. Culwell, Department of Biology, University of Central Arkansas at Conway.

UNDERSTORY BIOMASS FOR ENERGY.
Timothy T. Ku and Charles R. Blinn, Department of Forestry, University of Arkansas at Monticello and James B. Baker, U.S. Forest Service, Southern Forest Experiment Station at Monticello.

PRELIMINARY ANALYSIS OF THE GLO TREE DATA FROM TOLTEC STATE PARK NEAR LITTLE ROCK.
Nancy G. McCartney, University of Arkansas Museum at Fayetteville.

VEGETATION COMMUNITIES OF THE CENTRAL MISSISSIPPI DELTA REGION AND THEIR RELATION TO FLOODING.
Edward E. Dale, Jr., Department of Botany and Bacteriology, University of Arkansas at Fayetteville, and R. T. Huffman, Environmental laboratory, Waterways Experiment Station, Corps of Engineers, Vickesburg, Mississippi.

PRELIMINARY REPORT ON THE FLORA OF INDEPENDENCE COUNTY, ARKANSAS.
Veryl V. Board, Health and Sciences program, Arkansas College at Batesville.

LITERATURE ON THE VEGETATION OF ARKANSAS: AN UPDATED LIST.
Bill Pell, The Nature Conservancy at Little Rock.

AN UPDATE ON THE NATURE CONSERVANCY'S ARKANSAS HERITAGE PROGRAM.
Ken Smith, Arkansas Heritage Program at Little Rock.

RESPONSE OF MAIZE TO TWO ROCK PHOSPHATE FERTILIZERS.
M. R. Majedi and L. F. Thompson, Department of Agronomy, University of Arkansas at Fayetteville.

A COMPARISON OF EARLY GROWTH AND SOIL ADAPTATION OF SELECTED BUSH *LESPEDEZA* SPP. (LEGUMINOSAE) ON SOILS OF NORTHEAST ARKANSAS.
S. A. Sewell and A. W. Tennille, Department of Biological Sciences and College of Agriculture at Arkansas State University.

A CHECKLIST OF ARKANSAS LICHENS.
Jewel E. Moore, Biology Department, University of Central Arkansas at Conway.

MORPHOLOGICAL VARIATION IN THE DIATOM *RHOPALODIA GIBBA* (EHRENBERG) MULLER.
David B. Czarnecki and Richard L. Meyer, Dept. of Botany and Bacteriology, University of Arkansas at Fayetteville and Dean W. Blinn, Dept. of Biological Science, Northern Arizona University at Flagstaff, Arizona.

SECONDARY SYMMETRY IN DIATOMS: TAXONOMIC IMPLICATIONS OF A CLONE OF AN ABERRANT *GOMPHONEMA SUBCLAVATUM* (GRUNOW) GRUNOW FROM NORTHWESTERN ARKANSAS.
Richard L. Meyer and David B. Czarnecki, Dept. of Botany and Bacteriology, University of Arkansas at Fayetteville.

AQUATIC ENVIRONMENT I
Section Chairman: John K. Beadles

INTENSIVE CULTURE OF THE WHITE AMUR BY THE USE OF CAGES.
Tommy G. Crawford and John K. Beadles, Arkansas State University, State University, Arkansas.

A PRECHANNELIZATION ICHTHYOFAUNAL SURVEY OF MAIN DITCH, RANDOLPH COUNTY, ARKANSAS.
Steve M. Bounds, Crowley's Ridge College.

INTERRENAL GLAND RESPONSE TO HYPOXIA IN THE CHANNEL CATFISH *(ICTALURUS PUNCTATUS)*.
J. R. Tomasso, K. B. Davis, and N. C. Parker, Memphis State University, Memphis, TN.

FOOD OF THE LARGEMOUTH BASS *(MICROPTERUS SALMOIDES)* IN DEGRAY RESERVOIR, ARKANSAS, 1976.
Horace Bryant and Thomas E. Moen, U.S. Fish and Wildlife Service, Arkadelphia, Arkansas.

EVALUATION OF A FUL-FAT SOYBEAN RATION FOR CHANNEL CATFISH PRODUCTION IN CAGES.
Scott H. Newton, Walter R. Robison and Calvin J. Haskins, University of Arkansas at Pine Bluff.

POTENTIAL OF UTILIZING SCRAP PROCESSED CHEESE AS A MAJOR CATFISH RATION COMPONENT.
Calvin J. Haskins and Scott H. Newton, University of Arkansas at Pine Bluff.

GROWTH AND YEAR-CLASS COMPOSITION OF WHITE BASS *(MORONE CHRYSOPS)* IN DEGRAY LAKE, ARKANSAS.
Thomas E. Moen and Michael R. Dewey, U.S. Fish and Wildlife Service, Arkadelphia, Arkansas.

GROWTH AND STANDING CROP OF LARGEMOUTH BASS *(MICROPTERUS SALMOIDES)* FROM LAKE ELMDALE.
Alex Zdinak, Jr., Raj V. Kilambi, Marvin Galloway, John D. McClanahan and Clark Duffe, University of Arkansas at Fayetteville.

PRELIMINARY REPORT ON THE BIOLOGY OF THE YELLOW-CHEEK DARTER, *ETHEOSTOMA MOOREI* RANEY AND SUTTKUS.
Roland E. McDaniel and George L. Harp, Arkansas State University, State University, Arkansas.

SCIENCE EDUCATION
Section Chairman: Neal Buffaloe

THE ORGANIZATION AND DEVELOPMENT OF A METHODS COURSE FOR SECONDARY SCIENCE MAJORS.
Earl L. Hanebrink, Arkansas State University, State University, Arkansas.

MODEL FOR DEMONSTRATION OF ORGANIC REACTION MECHANISMS.
Paul M. Nave, Arkansas State University, State University, Arkansas.

ASTRONOMY ACTIVITIES: AN EXCITING, FLEXIBLE ALTERNATIVE TO TRADITIONAL LAB SESSIONS.
Carl T. Rutledge, Southern Arkansas University, Magnolia, Arkansas.

INNOVATIVE LABORATORY EXERCISES FOR GENERAL BOTANY.
Robert D. Wright, Donald E. Culwell, and Jewel E. Moore, University of Central Arkansas, Conway, Arkansas.

AN APPRAISAL OF COLLEGE SCIENCE COURSES BY IN-SERVICE HIGH SCHOOL SCIENCE TEACHERS.
Robert T. Kirkwood, University of Central Arkansas, Conway, Arkansas.

A REPORT ON THE STATUS AND DISTRIBUTION OF THE RED-COCKADED WOODPECKER IN ARKANSAS.
Fred Burnside and Douglas James, University of Arkansas at Fayetteville.

STUDIES ON THE BIOLOGY OF THE STONEFLY NYMPH *NEOPHASGANOPHORA* SP. (PLECOPTERA) FROM NORTHWESTERN ARKANSAS.
James R. Briggs, College of the Ozarks, Clarksville, Arkansas.

GEOLOGY
Section Chairman: Walter Manger

STRATIGRAPHY OF THE BRENTWOOD AND WOOLSEY MEMBERS, BLOYD FORMATION (TYPE MORROWAN), NORTHWESTERN ARKANSAS.
Thomas A. McGilvery and Charles F. Berlau, Department of Geology, University of Arkansas at Fayetteville.

CARBONATE PETROGRAPHY OF THE BRENTWOOD MEMBER, BLOYD FORMATION (TYPE MORROWAN), NORTHWESTERN ARKANSAS.
Charles E. Berlau and Thomas A. McGilvery, Department of Geology, University of Arkansas at Fayetteville.

THICKNESS AND AERAL EXTENT OF THE CHATTANOOGA SHALE IN ARKANSAS, OKLAHOMA AND MISSOURI.
Steven H. Terry, Department of Geology, University of Arkansas at Fayetteville.

ANATOMY OF A FLUVIAL SHEET SANDSTONE, NORTHWEST ARKANSAS.
R. Keith Crowder, Department of Geology, University of Arkansas at Fayetteville.

MAGNETIC INTENSITY AND BOUGUER GRAVITY OF THE CENTRAL ARKOMA BASIN OF ARKANSAS.
John H. McBride, Department of Geology, University of Arkansas at Fayetteville.

MERCURY IN WATERS OF NORTHWEST ARKANSAS, SOUTHWEST MISSOURI, AND NORTHEAST OKLAHOMA.
Larry Barber II and Kenneth F. Steele, Department of Geology, University at Fayetteville.

SURFACE AND SUBSURFACE TEMPERATURES (SILICA THERMOMETRY) OF THE OUACHITA MOUNTAINS SPRING WATERS.
George H. Wagner and Kenneth F. Steele, Department of Geology, University of Arkansas at Fayetteville and John B. Sharp, Phillips Coal Company, Woodgate Office Park, Suite 200, 1121 E. Southeast Loop 323, Tyler, Texas 75703.

INVERTEBRATE ZOOLOGY
Section Chairman: Robert Watson

*A CHECKLIST OF THE RECENT MOLLUSCA OF ARKANSAS.
Mark E. Gordon, Department of Zoology, University of Arkansas at Fayetteville.

*SIGNIFICANT ADDITIONS TO THE MOLLUSCAN FAUNA OF THE ILLINOIS RIVER, ARKANSAS.
Mark E. Gordon and Arthur V. Brown, Department of Zoology, University of Arkansas at Fayetteville.

A STUDY OF THE ANATOMY OF THE ALIMENTARY CANAL OF *BROCHYMENA QUADRIPUSTULATA* (HEMIPTERA: PENTATOMIDAE).
Dan T. Barber, Lynita M. Cooksey and David H. Abell, Department of Biological Sciences, Arkansas State University, State University, Arkansas.

OBSERVATIONS ON THE INCIDENCE OF CHIGGERS, *EUTROMBICULA ALFREDDUGESI* (OUDEMANS) ON CROTAPHYTUS (SAURIA: IGUANIDAE) IN IZARD COUNTY, ARKANSAS.
Chris T. McAllister, Department of Biological Sciences, Arkansas State University, State University, Arkansas.

A CONTINUATION OF SPIDER RESEARCH IN ARKANSAS: GULF COASTAL PLAINS.
Peggy Rae Dorris, Department of Biology, Henderson State University at Arkadelphia.

HETEROCHROMATIC PATTERNS IN *DROSOPHILIA VIRILIS* INTERPHASE NUCLEI.
William C. Guest, Department of Zoology, University of Arkansas at Fayetteville.

SOME EFFECTS OF METHYL GREEN ON EXPRESSION OF DAMAGE INDUCED IN G_1 XENOPUS CELLS BY ULTRAVIOLET LIGHT.
Keith Mathias and Gaston Griggs, John Brown University at Siloam Springs.

THE EFFECT OF SANGINARINE ON SODIUM-POTASSIUM ACTIVATED ADENOSINE TRIPHOSPHATASE FROM FROG SKIN.
James R. Nichols and K. D. Straub, Department of Biology, University of Central Arkansas at Conway, and Medical Research Service, VA Hospital, Departments of Biochemistry and Medicine, University of Arkansas for Medical Sciences at Little Rock.

VERTEBRATE ZOOLOGY
Section Chairman: Dennis Baeyens

A CHECKLIST AND KEY TO THE AMPHIBIANS OF ARKANSAS.
James M. Walker and Robert Brewer, Department of Zoology, University of Arkansas at Fayetteville.

A CHECKLIST AND KEY TO THE REPTILES OF ARKANSAS.
James M. Walker and Robert Brewer, Department of Zoology, University of Arkansas at Fayetteville.

HERPTOFAUNA ON THE RED RIVER AND ITS OXBOWS: FOUR COUNTIES OF SOUTHWEST ARKANSAS.
Sandra K. Ball and Peggy R. Dorris, Department of Biological Sciences, Henderson State University at Arkadelphia.

PARAMETERS OF FOOD AND HABITAT PARTITIONING IN A COMMUNITY OF SYMPATRIC INSECTIVOROUS BATS.
Ken N. Paige and V. Rick McDaniel, Department of Biological Sciences, Arkansas State University.

THE PRESENCE OF *HAEMOGREGARIANA* (PROTOZOA: SPOROZOA) IN THE RED-EARED SLIDER, *CHRYSEMYS SCRIPTA ELEGANS* (Wied) from Lonoke County, Arkansas.
Chris T. McAllister and Anthony W. King, Department of Biological Sciences, Arkansas State University and James J. Daly, Department of Microbiology and Immunology, University of Arkansas for Medical Sciences at Little Rock.

SEXUAL DIETARY DIFFERENCES IN A POPULATION OF *TRIONYX MUTICUS* (REPTILIA: TESTUDINES).
Michael V. Plummer and David B. Farrar, Department of Biology, Harding University at Searcy and Department of Entomology, University of Kansas at Lawrence, Kansas.

EVAPORATIVE WATER LOSS IN *OPHEODRYS AESTIVUS* WITH A COMPARISON TO *O. VERNALIS*.
L. A. Bell, D. A. Baeyens and M. V. Plummer, Department of Biology, Harding University at Searcy and Department of Biology, University of Arkansas at Little Rock.

*OVERWINTERING HELMINTHS OF THE COMMON MALLARD, *ANAS PLATYRHYNCHOS PLATYRHYNCHOS*, IN ARKANSAS.
Mary Elizabeth McKenzie, Department of Biology, Hendrix College at Conway.

*RECENT INVESTIGATIONS OF *ACUARIA* (CHEILOSPIRURA) (NEMATODA: SPIRURATA: ACUARIIDAE) IN THE COMMON GRACKLE *(QUISCALUS QUISCULA)* IN ARKANSAS.
Ann O. Black and Arthur A. Johnson, Hendrix College at Conway.

SAGE THRASHER, *OREOSCOPTES MONTANUS*, A NEW SPECIES FOR ARKANSAS.
Norman Lavers, Department of English, Arkansas State University.

GROWTH PATTERNS, BEHAVIOR AND FOOD ITEMS FED TO NESTLING GREAT HORNED OWLS *(BUBO VIRGINIANUS)*.
Rodney Harris and Earl Hanebrink, Department of Biological Sciences, Arkansas State University.

SUCCESS OF NATIVE-TRAPPED COMPARED TO CAPTIVITY-RAISED BIRDS IN RESTORING WILD TURKEY POPULATIONS TO NORTHWESTERN ARKANSAS.
Douglas James, L. Glen Fooks and John R. Preston, University of Arkansas at Fayetteville, Southern Baptist College at Walnut Ridge, and Oklahoma City Zoo at Oklahoma City, Oklahoma.

ECOLOGICAL OBSERVATIONS OF THE EASTERN COLLARED LIZARD, *CROTAPHYTUS COLLARIS COLLARIS* (SAY) IN NORTH-CENTRAL ARKANSAS, WITH COMMENTS ON SOCIAL BEHAVIOR.
Chris T. McAllister, Arkansas State University.

A HAND-HELD BROADBAND ULTRASONIC DETECTOR FOR MONITORING BAT CRIES IN THE FIELD.
Ken N. Paige and Lawrence A. Mink, Department of Biological Sciences and Department of Mathematics and Physics, Arkansas State University.

PROFILE OF THE STRIPED SKUNK RABIES EPIDEMIC IN ARKANSAS.
Gary A. Heidt, James Lammers, and Dale V. Ferguson, Department of Biology, University of Arkansas at Little Rock.

DISEASE PROFILE OF STRIPED SKUNKS *(MEPHITIS MEPHITIS)* FROM A PUBLIC USE AREA.
Dale V. Ferguson, Robin G. Heidt and Gary A. Heidt, Department of Biology, University of Arkansas at Little Rock.

WILDLIFE HABITAT MANAGEMENT ON THE OUACHITA NATIONAL FOREST.
David A. Saugey, U.S. Forest Service, Ouachita National Forest at Hot Springs.

AQUATIC ENVIRONMENT II
Section Chairman: John K. Beadles

IMPLICATIONS AND CONSIDERATIONS CONCERNING THE STATUS, HABITAT, AND DISTRIBUTION OF THE LEAST BROOK LAMPREY, *LAMPETRA AEPYPTERA* (ABBOT) PISCES: PETROMYZONTIDAE) IN ARKANSAS, BASED ON RECENT RECORDS.
S. A. Sewell, F. A. Carter and C. T. McAllister, Arkansas State University, State University, Arkansas.

THE SYSTEMATIC STATUS OF THE FISHES OF GENUS *CAMPOSTOMA* (CYPRINIDAE) INHABITING THE MAJOR DRAINAGES OF NORTHERN ARKANSAS.
S. A. Sewell, J. K. Beadle and V. R. McDaniel, Arkansas State University, State University, Arkansas.

THE MAYFLIES OF NORTHEAST ARKANSAS.
Nelson A. Childers and George L. Harp, Arkansas State University, State University, Arkansas.

BENTHIC COMMUNITY STRUCTURE, THE ENDANGERED SPECIES LAW AND THE NEW WHITE RIVER BRIDGE AT ST. CHARLES, ARKANSAS.
Louise R. Karemer, Mark Gordon and Edgar Short, University of Arkansas at Fayetteville.

AN INVENTORY OF THE DECAPOD CRUSTACEANS (CRAYFISH AND SHRIMPS) OF ARKANSAS, WITH A DISCUSSION OF THEIR GENERAL HABITATS.
Raymond W. Bouchard and Henry W. Robison, Southern Arkansas University, Magnolia, Arkansas.

THE AQUATIC MACROINVERTEBRATES OF WAPANOCCA NATIONAL WILDLIFE REFUGE.
George L. Harp and Phoebe A. Harp, Arkansas State University, State University, Arkansas.

THE FISHES AT ROCK CREEK, SHARP COUNTY, ARKANSAS.
F. Allen Carter and J. K. Beadles, Arkansas State University, State University, Arkansas.

THE WATER STRIDERS (HEMIPTERA: GERRIDAE) OF ARKANSAS.
Paul D. Kittle, University of North Alabama, Florence, Alabama.

AN INVESTIGATION OF THE STREAM BED OXYGEN DEMAND OF FOURCHE CREEK, PULASKI COUNTY, ARKANSAS.
Patrick Edelmann and John D. Rickett, University of Arkansas at Little Rock.

MIXING IN DARDANELLE LAKE: CONCENTRATIONS OF SELECTED CATIONS.
D. M. Chittenden II, Arkansas State University, State University, Arkansas.

DARDANELLE LAKE: A SOLUTION APPROACHING EQUILIBRIUM.
D. M. Chittenden II, Arkansas State University, State University, Arkansas.

THE EFFECTS OF STRATIFICATION ON LAKE FRIERSON.
Larry W. Dorman and John K. Beadles, Arkansas State University, State University, Arkansas.

HYDROGEOLOGY
Section Chairman: Albert Ogden

A PRELIMINARY INVESTIGATION OF RURAL USE AQUIFERS OF NORTHERN SEARCY COUNTY, ARKANSAS.
Wyndal M. Goodman and Albert E. Ogden, Department of Geology, University of Arkansas at Fayetteville.

A PRELIMINARY INVESTIGATION OF THE GROUND-WATER RESOURCES OF BAXTER COUNTY, ARKANSAS.
Michael F. Liebelt and Albert E. Ogden, Department of Geology, University of Arkansas at Fayetteville.

A PRELIMINARY INVESTIGATION OF THE GROUND-WATER RESOURCES OF SHARP, FULTON, AND IZARD COUNTIES, ARKANSAS.
Gerald W. Lundy and Albert E. Ogden, Department of Geology, University of Arkansas at Fayetteville.

CONTAMINATION OF BOONE-ST. JOE LIMESTONE GROUNDWATER BY SEPTIC TANKS AND CHICKEN HOUSES.
Gerald D. Cox and Albert E. Ogden, Department of Geology, University of Arkansas at Fayetteville.

USE OF THE TRI-POTENTIAL METHOD OF RESISTIVITY IN LOCATING CAVES, FRACTURES AND FAULTS.
Paul S. Eddy, Jr., and Albert E. Ogden, Department of Geology, University of Arkansas at Fayetteville.

PSYCHOLOGY
Section Chairman: Chris Spatz

*EFFECTS OF BACKGROUND MUSIC: TWO REPLICATIONS OF MAY AND HAMILTON (1977).
Diane Wimberley and Kathy Gladstone, Hendrix College at Conway.

*A METHOD FOR PLACING A CAMMULA IN THE COMMON CAROTID ARTERY OF THE ADULT RAT: A CHRONIC PREPARATION.
Tom Wilhite, Hendrix College at Conway.

REWARD SEQUENCE AND AVERAGE REWARD AMOUNT AS DETERMINANTS OF RESPONSE PERSISTENCE TO THE NEGATIVE STIMULUS IN DISCRIMINATION LEARNING.
Steven J. Haggbloom, Department of Counselor Education and Psychology, Arkansas State University.

INFLUENCE OF GENDER APPROPRIATENESS OF SEX-ROLE AND OCCUPATIONAL PREFERENCES ON EVALUATIONS OF A COMPETENT PERSON.
Robert D. Johnson, Department of Psychology, Arkansas State University and David R. Shaffer, Department of Psychology, University of Georgia at Athens, Georgia.

EFFECTS OF PRECEDING REINFORCEMENT MAGNITUDE ON FIXED-INTERVAL PERFORMANCE IN PIGEONS.
Lynn Howerton, Department of Counselor Education and Psychology, Arkansas State University.

THE RELATIVE BEHAVIORAL CONTROL EXERCISED BY INTERNAL REWARD-PRODUCED STIMULI AND EXTERNAL STIMULI IN RATS' DISCRIMINATION LEARNING.
David J. Tillman and Steven J. Haggbloom, Department of Counselor Education and Psychology, Arkansas State University.

BIOMEDICAL SCIENCE
Section Co-Chairmen: John E. Pauly and Lawrence E. Scheving

SPECIES DIFFERENCES IN NA,K-ATPASE INHIBITORY ACTIONS AND POSITIVE INOTROPIC EFFECTS OF SANGUANARINE.
R. Kirk Riemer, Ernest Seifen and Robert J. Adams, Department of Pharmacology, College of Medicine, University of Arkansas for Medical Sciences, Little Rock, Arkansas 72205.

ALTERATIONS OF VENTRICULAR β-ADRENERGIC AND H_1-HISTAMINERGIC RECEPTORS IN GUINEA PIGS ADAPTED TO SIMULATED HIGH ALTITUDE.
Kim F. Light, College of Pharmacy, University of Arkansas for Medical Sciences, Little Rock, Arkansas 72205.

EVIDENCE FOR 1,25DIHYDROXYCHOLECALCIFEROL (1,25DHCC) MODULATION OF PARATHYROID GLAND METABOLISM STUDIED *IN VITRO*.
William Y. W. Au, Jeanne A. Murphy and Richard F. Williams, Departments of Pharmacology and Medicine, College of Medicine, University of Arkansas for Medical Sciences and VA Medical Center, Little Rock, Arkansas 72201.

LOCATION AND ACTIVATION OF LONG DESCENDING PROPRIOSPINAL NEURONS IN CAT SPINAL CORD.
Robert J. Adams, Robert D. Skinner and Ronald S. Remmel, Departments of Anatomy and Physiology, College of Medicine, University of Arkansas for Medical Sciences, Little Rock, Arkansas 72205.

CONNECTIONS OF THE MESENCEPHALIC LOCOMOTOR REGION (MLR).
E. Garcia-Rill, R. D. Skinner and S. A. Gilmore, Department of Anatomy, College of Medicine, University of Arkansas for Medical Sciences, Little Rock, Arkansas 72205.

HOW WE LOOK: STUDIES OF OCULOMOTOR-SYSTEM NEURAL CONNECTIONS.
Ronald S. Remmel and Robert D. Skinner, Departments of Physiology and Anatomy, College of Medicine, University of Arkansas for Medical Sciences, Little Rock, Arkansas 72205.

SOME NEUROCHEMICAL CHARACTERISTICS OF THE GENETICALLY NERVOUS DOG.
Donald C. De Luca, Charles Angel and Letha H. Couch, Department of Biochemistry, University of Arkansas for Medical Sciences, Little Rock, Arkansas 72205.

NEUROTOXIC EFFECTS OF METHYLMERCURY ON DORSAL ROOT GANGLIA.
Rick Y. Yip and Louis W. Chang, Department of Pathology, College of Medicine, University of Arkansas for Medical Sciences, Little Rock, Arkansas 72205.

TETRAETHYLLEAD (TEL) INDUCED ULTRASTRUCTURAL CHANGES IN THE KIDNEY.
Paul R. Wade, Victoria L. Wade, Joyce L. Lillo and Louis W. Chang, Department of Pathology, College of Medicine, University of Arkansas for Medical Sciences, Little Rock, Arkansas 72205.

THE EFFECT OF COLD SHOCK ON THE METABOLISM OF *TRICHOMONAS GALLINAE*.
James J. Daly, Department of Microbiology and Immunology, College of Medicine, University of Arkansas for Medical Sciences, Little Rock, Arkansas 72205.

THE DISTRIBUTION OF *NAEGLERIA FOWLERI* IN SELECTED NORTHEAST ARKANSAS LAKES.
Robert D. Evans and Lawrence W. Hinck, Department of Biological Sciences, Arkansas State University, State University, Arkansas 72467.

IMMUNE RESPONSES OF RATS TO ANTIGENS OF MOLONEY LEUKEMIA VIRUS (MULV).
Frances B. Soderberg, Susan G. Tai and Joe M. Jones, Department of Pathology, College of Medicine, University of Arkansas for Medical Sciences, Little Rock, Arkansas 72205.

ZINC CONCENTRATION IN TISSUES OF ETHANOL PREFERRING AND NON-PREFERRING MICE.
Richard E. Stull and James N. Pasley, Department of Biopharmaceutical Sciences, College of Pharmacy, and Department of Physiology and Biophysics, College of Medicine, University of Arkansas for Medical Sciences, Little Rock, Arkansas 72205.

EFFECTS OF CHRONIC ACTH INJECTIONS ON ETHANOL SELECTION IN INTACT AND ADRENALECTOMIZED MICE.
M. J. Kassam and J. N. Pasley, Department of Physiology and Biophysics, College of Medicine, University of Arkansas for Medical Sciences, Little Rock, Arkansas 72205.

THE RESPONSE OF RHESUS MONKEYS TO CHOLESTEROL FEEDING.

Manford D. Morris and Charles A. Nelson, Departments of Pediatrics and Biochemistry, College of Medicine, University of Arkansas for Medical Sciences, Little Rock, Arkansas 72205.

INCIDENCE OF HYPERPROLACTINEMIA IN MALE GERIATRIC PATIENTS.

Joseph W. Kittinger, Peter O. Kohler and Louis R. Pryor, Department of Medicine, College of Medicine, University of Arkansas for Medical Sciences, Little Rock, Arkansas 72205.

Arkansas Collegiate Academy of Science

Frank Brown
President

Jane Spradley
President-Elect

Pam Brown
Secretary-Treasurer

Sponsor: Dr. Ed Wilson

MINUTES OF THE BUSINESS MEETING, 28 MARCH 1980

The meeting was called to order at 11:04 A.M. The following persons were present:

From Harding University — Frank Brown, Pam Brown
From Hendrix University — Ann Black, Beth McKenzie, Jane Spradley
From College of the Ozarks — James Briggs
Professors — Ron Doran, Dr. James Mackey, Dr. E. W. Wilson, Jr.

The president, Frank Brown, handed out copies of the constitution and discussed the section about officer selection. It was noted that the president and president-elect may not be from the same school. It was also noted that the president chooses the secretary. It was recommended that the treasurer of the Senior Academy keep the money for the Collegiate Academy because of some problems with Worthen Bank. Pam Brown made the motion that we elect no treasurer this year, but retain the right to do so in later years if members feel it would be useful. Jane Spradley seconded the motion, and it was accepted unanimously.

Nominations were opened for the office of president-elect. James Briggs was nominated and elected unanimously. He suggested Dr. John F. Bridgeman as sponsor.

Dr. E. W. Wilson, Jr. suggested that Jane Spradley give a report at the Senior Academy meeting.

Jane Spradley moved that we accept the constitution handed out at the beginning of the meeting as the official constitution. James Briggs seconded the motion. All present were in favor of the motion.

Frank Brown handed the presidency over to Jane Spradley. Jane introduced herself and there was some discussion about increasing the activities of the Collegiate Academy. Jane said she would name her secretary and sponsor after talking with the people she had in mind.

Frank Brown motioned to adjourn the meeting. James Briggs seconded the motion. All were in favor. The meeting was adjourned at 11:30 A.M.

Respectfully Submitted,

Pam Brown
Secretary
Arkansas Collegiate Academy
1979-80

ABSTRACTS OF PAPERS PRESENTED BY COLLEGIATE ACADEMY MEMBERS

Editor's Note: Not included in the following abstracts are those of Mark E. Gordon, whose papers were accepted for publication and are presented elsewhere. Titles of papers presented by Collegiate Academy members are identified in the preceding Section Programs by *

EVAPORATIVE WATER LOSS IN *OPHEODRYS AESTIVUS* WITH A COMPARISON TO *O. VERNALIS*.

L. A. Bell, D. A. Baeyens, and M. V. Plummer. Department of Biology, Harding University, Searcy, Arkansas 72143 and Department of Biology, University of Arkansas at Little Rock (D.A.B.), Little Rock, Arkansas 72204.

Previous studies of cutaneous water loss in terrestrial and fossorial reptiles have shown lower rates in forms from xeric habitats than in forms from mesic habitats. We hypothesize that arboreal forms may be adapted to lose less water than a comparative terrestrial form because of the large surface area that is continuously exposed to desiccating air currents. We compared rates of water loss of *Opheodrys aestivus* (arboreal) with that of *O. vernalis* (terrestrial) in a dry air flowing chamber. Adult *O. vernalis* lost statistically more water than adult *O. aestivus*. However, rate of water loss in *O. aestivus* was highly dependent upon body size. We were unable to determine body size relationships for *O. vernalis* because of a small sample size. We conclude that in order to adequately make interspecific comparisons one must compare regression equations of water loss on body size and not simply means as has been done in the literature. Despite this restriction *O. aestivus* appears to lose less water than many snakes except for forms adapted for extreme aridity and for the vipers. This low rate may be an adaptation for arboreality.

RECENT INVESTIGATIONS OF *ACUARIA (CHELILOSPIRURA)* (NEMATODA: SPIRURATA: ACUARIIDAE) IN THE COMMON GRACKLES *QUISCALUS QUISCULA* IN ARKANSAS.

Ann O. Black and Arthur A. Johnson, Dept. of Biology, Hendrix College, Conway, Arkansas 72032.

Gizzards of 50 (25 male, 25 female) wintering common grackles in Arkansas yielded 51 nematodes of the Genus *Acuaria (Cheilospirura)*. The nematodes were found in small numbers immediately under the cornified layer of the gizzard. Female hosts were more frequently infected than the male hosts. The sex ration of the parasite was the same for both sexes of host. This is the first report of the Genus *Acuaria* in common grackles in the central United States. A description of the parasite and its bionomics are discussed.

THE CRYSTAL AND MOLECULAR STRUCTURE OF TRANS-TRANS-μ-CHLORO-μ-PYRAZOLATODICHLORO-BIS-(ETHYLENE) DIPLATINUM (II), Cl (C_2H_4) Pt (μ-Cl) (μ-$C_3N_2H_3$) Pt (c_2H_4) Cl.

A. W. Cordes, W. C. Deese, D. A. Johnson, Dept. of Chemistry, University of Arkansas at Fayetteville, 72701.

The pyrazole molecule is an extremely versatile ligand binding as a neutral monohapto, anionic monohapto, and anionic dihapto bridging group in various complexes. Complexes containing a single 1,2-dihapto pyrazolide ligand are relatively rare; however, the title complex which is obtained as one of the products of the reaction of Zeise's anion ($PtCl_3C_2H_5^-$) with pyrazole in aqueous solution contains a single bridging azaromatic anion.

The title complex crystallizes in the $P2_1/n$ space group. The unit cell contains four molecules and has dimensions a = 8.099 Å, b = 17.189 Å, c = 9.895 Å and β = 116.86°. Manual diffractometer data for 1198 independent reflections was refined by full matrix least squares methods to an R = 0.050. Exclusive of the ethylene moities, the molecule is nearly planar; for example, the dihedral angle between the two PCl_2N coordination planes is 172°. The platinum-platinum distance within a single molecule is 3.717 Å with platinum-platinum contacts between neighboring molecules at 4.027 and 4.232 Å.

OVERWINTERING HELMINTHS OF THE COMMON MALLARD, *ANAS PLATYRHYNCHOS PLATYRHYNCHOS*, IN ARKANSAS.

Mary Elizabeth McKenzie, Dept. of Biology, Hendrix College, Conway, Arkansas 72032.

Twenty one male and 19 female common mallards, *Anas platyrhynchos platyrhynchos*, were collected from two locations in Arkansas during the period between 13 December, 1979 and 29 February, 1980. Birds were dispatched and the viscera were immediately examined. Fourteen genera of helminths were found (four cestodes, five trematodes and five nematodes). Parameters for statistical analysis involve host sex, weight, and flock. Helminth distribution in the host was recorded by organ system, organ, and organ part. The prevalence of parasites, infection intensity, and numbers of species of helminths per host were noted.

SYNTHESIS OF N-SUBSTITUTED ANALOGS OF ACYCLIC NARCOTIC ANALGESICS AS NARCOTIC ANTAGONISTS.

J. B. Richardson, P. K. Raible, D. L. Green, and D. L. Lattin, Dept. of Biopharmaceutical Sciences, College of Pharmacy, University of Arkansas for Medical Sciences, Little Rock, Arkansas 72205.

It is well established that potent narcotic antagonists can be prepared by substituting allyl or cyclopropylmethyl alkyl groups for the methyl groups on the tertiary nitrogen of many narcotic analgesics. This structural modification is effective when using narcotic analgesics derived from morphine, morphinan, and benzomorphan. In an effort to prepare acyclic narcotic antagonists, we have synthesized analogs of acetylmethadol and methadol possessing the same structural modifications. The allyl and cycloprophylmethyl alkyl groups are substituted for one of the methyl groups on the tertiary nitrogen. The synthesis of these compounds, and preparation of salts suitable for pharmacological testing, will be discussed.

SYNTHESIS OF PENTAPEPTIDES AS MORPHINE AGONISTS AND ANTAGONSISTS.

K. Lee Robinson, Lyle Van Arsdale and A. Nelson Voldeng, College of Pharmacy, University of Arkansas for Medical Sciences, Little Rock, Arkansas 72205.

Enkephalins are endogenous peptides composed of five amino acids (Met^5-enkephalin = tyr-gly-gly-phe-met) and have been shown to elicit brief, but remarkable opiate-like analgesic activity when tested in laboratory animals. Comparison of the conformations of the enkephalins with the rigid structure of morphine have been reported by several groups in an attempt to define the features of the brain's opiate receptors which modulate pain perception. Unfortunately the proposed enkephalin conformations do not satisfy many of the proposed pictures of the opiate receptors, nor do they explain the basis for opiate antagonism exhibited by certain morphine derivatives. Discussion will include rationale for synthesis of specific enkephalin derivatives which more closely conform to the structure of morphine, will be longer acting than the naturally occurring enkephalins, will be effective when administered orally, and synthetic procedures utilized to prepare these opiate agonists-antagonists.

A METHOD FOR PLACING A CANNULA IN THE COMMON CAROTID ARTERY OF THE ADULT RAT: A CHRONIC PREPARATION.

Tom Wilhite, Dept. of Psychology, Hendrix College, Conway, Arkansas 72032.

A method is described for the chronic cannulation of the right common carotid artery of the rat. An 8-inch length of size 20 polyethylene tubing is cut to a sharp point at one end. A 10-inch length of surgical silk is attached to the cannula with dental cement, approximately ¾ inch from the point. The animal is anesthetized, and the initial incision is made between the jaw and the shoulder, on the right side. Beneath the fascia, and beneath the overlapping region of the sternohyoid and sternomastoid muscle groups lies the carotid sheath. After the muscle groups are separated, the sheath is carefully pulled apart to reveal the nerves and vessels within. The carotid artery, the largest of the visible vessels, is isolated. After the artery is ligated posteriorly and clamped anteriorly, a small horizontal cut is made. The prepared cannula is inserted into the opening one-half inch. The thread attached to the cannula is then sutured into the surrounding muscles. An incision is made between the scapulae and the free end of the cannula exits there.

Such a cannula will allow the transfusion of blood into the primary supply to the brain. A later experiment will test the hypothesis that transfused blood from a satiated animal will act as a reinforcer for a hungry one.

EFFECTS OF BACKGROUND MUSIC: TWO REPLICATIONS OF MAY AND HAMILTON (1977).

Diane Wimberly and Kathy Gladstone, Dept. of Psychology, Hendrix College, Conway, Arkansas 72032.

May and Hamilton (1977) studied the unconscious effects of music on 30 females who were asked to evaluate either an attractive or an unattractive male stimulus photograph. The three levels of the independent variable were rock, avant-guard, and no music. It was hypothesized that significantly better ratings would occur under the rock music condition. Statistical tests supported this conclusion. In 1979, McKenna et al. did a study in which the unconscious effects of rock, free-form jazz, country, and classical music on stimulus photograph ratings were studied. They found no significant differences in the ratings assigned by 60 subjects on attractiveness, general intelligence, morality, knowledge of current events, and likeableness assigned to the photographs under the various music conditions. However, there was a decided tendency for ratings to be higher under music conditions than when no music was present. The insights and ideas obtained from the McKenna et al. experiment composed the basis for a third study (Wimberly and Gladstone, 1980). In this study, 41 species rated two photographs (one male and one female) under four different conditions: rock, country, classical, and control. The stimulus photographs were rated on attractiveness, general intelligence, morality, knowledge of current events, and likeableness on a 7 point Likert scale. No significant difference was found but the tendency for higher ratings to be assigned under the music conditions was, again, present. Final analysis combining the two experiments showed that the ratings with music indeed produced higher ratings.

ACTIVATION OF LONG DESCENDING PROPRIOSPINAL NEURONS IN CAT SPINAL CORD*

ROBERT J. ADAMS[1], ROBERT D. SKINNER[1] and RONALD S. REMMEL[2]
Department of Anatomy[1] and Department of
Physiology and Biophysics[2]
University of Arkansas for Medical Sciences
Little Rock, Arkansas 72205

ABSTRACT

Isolated mammalian spinal cord has been shown capable of generating locomotor activity. Propriospinal systems assumed to coordinate fore- and hindlimb activity are poorly understood. This study characterizes the long descending propriospinal (LDP) neurons in terms of the location of the somas and their peripheral inputs by direct neuronal recording. Anatomical studies using axonal retrograde transport of horseradish peroxidase from the lumbar to the cervical spinal cord as a tracer first described these neurons. Two hundred and thirty-one LDP neurons were identified in electrophysiological experiments. Of these, 123 responded to natural stimulation, and about 50% of the others were activated only by electrical stimulation. The majority of cells were located in laminae VII and VIII in agreement with anatomical data. The most effective stimuli were mechanical stimulation of skin, deep pressure to subcutaneous tissues, and paw joint movement. Bot excitatory and inhibitory responses were observed.

INTRODUCTION

The mammalian spinal cord isolated from the brain can generate the basic rhythm of locomotion (Sherrington, 1910; Brown, 1911; Grillner, 1975). A cat which has its spinal cord severed at the level of the first cervical vertebra can walk when its paws touch a moving treadmill, provided its weight is supported and it is chemically stimulated with the drug Clonidine® . The walking rhythm is quite normal, and there is good coordination between the fore- and hindlimbs. The neurons which possibly coordinate the fore- and hindlimbs are the subject of this report. One neuron which could subserve this function is the type illustrated at the top of Fig. 1. Its cell body lies in the cervical enlargement of the spinal cord, and its axon descends to the lumbosacral enlargement. Because it is entirely within the spinal cord, it is called a propriospinal neuron—a long descending propriospinal (LDP) neuron in this case.

The location of the cell bodies of the LDP neurons was recently determined in cat and monkey by injecting a tracer substance (horseradish peroxidase) into the lumbosacral enlargement. The tracer substance was picked up by the terminals of LDP neurons and transported back to the cell bodies in the cervical enlargement. They are found mainly in the medial part of the ventral horn of the spinal gray, but a few are in the dorsal horn (Skinner et al., 1979).

It is known that stimulation of afferents in a forelimb can elicit reflexes in the hindlimbs (Sherrington and Laslett, 1903). The route by which this occurs is depicted at the top of Fig. 1. Afferent nerve fibers from the forelimb entering the cervical enlargement activate short-axoned neurons called interneurons (IN), which in turn, activate the LDP neurons. The reflex is completed in the lumbosacral enlargement by LDP neurons activating other interneurons which finally activate motor neurons having axons that go to muscles which cause them to contract.

Our interest is in the types of sensory stimuli which, when applied to the forelimb, bring about activation of LDP neurons. In this study the types of effective stimuli, the region of the body which could be effectively stimulated (receptive field), and responses to electrical stimulation of peripheral nerves were investigated while recording the action potentials of single LDP neurons.

*Supported by USPHS Grants RR-05350 and NS-10304

METHODS AND MATERIALS

In adult cats initially anesthetized with Ketamine® (15 mg/kg), the carotid arteries were tied and the trachea was cannulated. The spinal cord was severed at the C1 level. Blood pressure was maintained above 90 mm Hg (mean arterial pressure) with intravenous fluids, and other vital functions were supported. Animals were mounted with the cervical spinal cord exposed. Glass micropipette electrodes were inserted into spinal cord segments C5-T2 until they were near a LDP cell. LDP neurons were identified by electrically stimulating their axons at the upper end of the lumbosacral enlargement (S in Fig. 1); this caused an action potential in the axon which propagated to the cell body where it was observed. Photographs of the action potentials were made from an oscilloscope screen. The arrival of action potentials in afferent fibers of the spinal cord was monitored with a ball-tipped electrode near the dorsal root entry zone.

Electrical stimulation of peripheral nerves was effected by single, constant current pulses of 0.1 msec duration delivered to the median, ulnar, or deep radial nerves through cuff wire electrodes. Natural stimulation consisted of hair movement, mechanical deformation of the skin, pressure to subcutaneous structures (deep pressure), and passive joint movement. Some of the stimuli were strong enough to be considered noxious.

RESULTS

Of 231 LDP neurons which were identified, 123 were activated by natural stimulation. Receptive fields of single LDP neurons for natural stimuli varied in size from one digit to the entirety of the forelimb; no receptive fields were found on the thorax, back, neck, or hindlimbs. Most receptive fields were found on the paws and upper arms, and almost one half of the responding neurons had more than one receptive field. Some had receptive fields on both forelimbs. Deep pressure proved to be the most frequently effective stimulus, followed by mechanical-cutaneous, and joint movement. About half of those not activated by natural stimuli were, however, activated by electrical stimulation of peripheral nerves.

Joint Movement: For 25 neurons the adequate stimulus was joint movement, mostly extension of the interphalangeal joints. Movement of the elbow joint was seldom effective. Unfortunately, the shoulder joint could not be adequately tested. Figure 1A-C shows the

responses of one LDP neuron which was activated by extension of metacarpo-phalangeal (MP) joints. In A, extension of the MP joints of the ipsilateral (same side) forelimb excited this neuron (bar denotes duration of extension). In B, extension of the MP joints of the contralateral (opposite) forelimb inhibited the firing of the cell evoked by extension of the ipsilateral MP joints. In C, the receptive fields for this cell are shown.

Deep Pressure: A common finding was that deep pressure applied to the belly or distal tendon of the triceps brachii muscle activated LDP neurons. Almost half of all receptive fields (51 neurons) were of this modality of stimulus.

Mechanical-Cutaneous: In this category, a few cells were activated by hair movement, while others required weak mechanical deformation of the skin (<5 gm), but some responded only to strong stimuli (5-40 gm). Forty-five neurons responded to this type of input.

Multimodal: Thirty-two neurons had receptive fields for two or more different modalities of stimuli.

Inhibition: A total of 24 inhibitory receptive fields were observed, in all cases, by a diminished response to an ongoing excitatory stimulus. An example of this is shown in Fig. 1A-C. Some LDP neurons had combinations of receptive fields such as excitatory areas on one upper arm and inhibitory fields on the paw of the opposite limb.

Electrical Stimulation: The purpose of nerve stimulation was to determine the degree of convergence from various forelimb areas onto single LDP neurons, and to determine the latency of activation. Of 105 cells tested, 68 were activated, 46 of these by stimulation of three nerves. No consistent differences were noted in the response characteristics of LDP neurons to deep radial (a pure muscular nerve) compared to median and ulnar (mixed cutaneous and muscular nerves). The mean latency (the time from the arrival of action potentials in afferent fibers at the spinal cord to the action potential in the LDP cell) was 6.6 ± 3.8 msec ($n = 68$), which suggests that one or more interneurons intervened. The latency of only one cell was short enough to suggest a monosynaptic connection (no intervening interneuron).

DISCUSSION

The principal findings of this study are: (1) several types of LDP neurons according to modality of stimulus to which they responded, (2) complex interactions of excitation and inhibition from different receptive fields of LDP neurons, and (3) convergence of input as from different receptive fields or peripheral nerves upon LDP neurons.

It is proposed that those LDP cells with mechanical cutaneous input might be involved in long spinal reflexes elicited by stimulation of the skin. Others, in particular those responsive to either joint movement or deep pressure, may function in relation to movements of the forelimbs. For example, the large group of cells activated by deep pressure to the triceps muscle might be active either during passive muscle stretch or during contraction. In either case, they could provide information as to the functional state of the limb during motor activity, such as locomotion.

Greater understanding of spinal mechanisms involved in motor activity and locomotion may lead to improved therapy for humans with spinal injury or disease.

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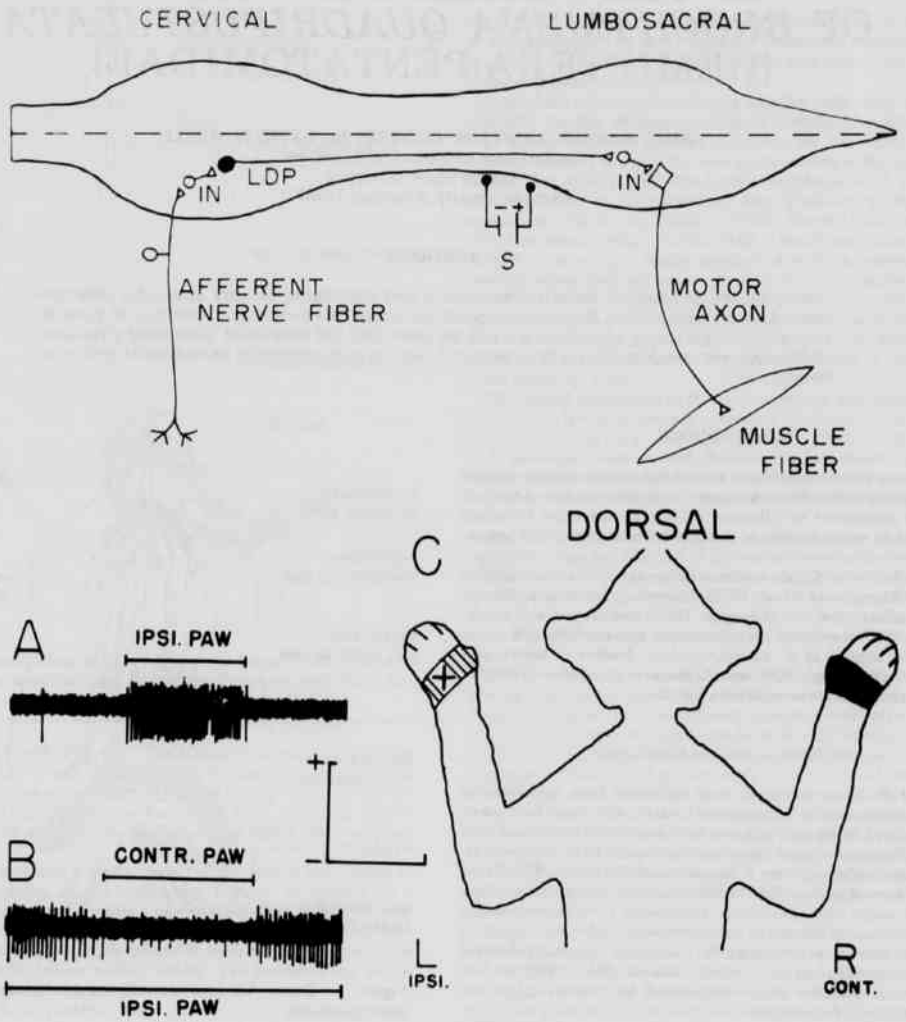

Figure 1. Top. Schematic drawing of isolated spinal cord and the reflex pathway from afferent fibers in the forelimb to motor neurons in the hindlimb. See text for explanation. IN = interneuron, LDP = long descending propriospinal neuron, S = electrical stimulator. In A-C are shown responses of an LDP neuron to extension of metacarpo-phalangeal (MP) joints. In A is shown the response of this cell to extension of the MP joints of the ipsilateral forelimb. Extension of the MP joints of the contralateral paw (B) could inhibit the firing of the cell evoked by extension of the ipsilateral MP joints. The receptive fields for this unit are shown in C. the plus sign (+) indicates an excitatory field and the negative sign (−) an inhibitory field. Another spike (smaller) was activated by extension of the contralateral MP joints. Horizontal bars indicate extension of the joints. Spikes were retouched. The calibration bars represent 0.4 sec and 1 mV.

A STUDY OF THE ANATOMY OF THE ALIMENTARY CANAL OF *BROCHYMENA QUADRIPUSTULATA* (HEMIPTERA:PENTATOMIDAE)

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ABSTRACT

An anatomical study of the alimentary canal and associated salivary apparatus was conducted for the pentatomid, *Brochymena quadripustulata*. The esophagus, ventriculus, pylorus, rectum, principal salivary glands and ducts are described and illustrated. Described structures of *Brochymena quadripustulata* are compared with various species of pentatomids and other hemipterans.

INTRODUCTION

Brochymena quadripustulata is one of the more common species of Pentatomidae in Northeast Arkansas. Except for studies of the gastric caecae conducted by Glasgow (1914), an extensive literature search failed to reveal studies of the internal anatomy of this hemipteran.

Previous studies of *Solubea pugnax* (Hamner, 1936), *Catacanthus incarnatus* (Ahmad and Afzal, 1978), *Murgantia histrionica* (Harris, 1936), *Peribalus limbolarius* (Glasgow, 1914), and *Chrysocoris patricius* (Kurup, 1963) were used for comparison and confirmation of the alimentary structures of *B. quadripustulata*. Studies of the coreids *Anasa tristis* (Breakey, 1936) and *Leptocoris trivittalus* (Glasgow, 1914) were also used for comparative purposes.

METHODS AND MATERIALS

Adults of *B. quadripustulata* were collected from mid-October through November 1979, in Craighead County, Arkansas. Live specimens were fixed in Bouin's solution for twenty-four hours and then stored in 70% ethanol until dissected. Specimens in the overwintering stage were collected from 9 January to 22 February 1980. These specimens were stored at 3-4°C until dissected, at which time they were anesthesized with chloroform. Esselbaugh (1948) reported that none of ten or more species of pentatomids placed in a refrigerator were able to survive, even though the specimens were not subjected to temperatures as low as they survive outdoors. We encountered no problems with mortality after refrigeration for periods up to two months with *B. quadripustulata*.

Access to the abdominal cavity and head capsule was facilitated by scissoring the flattened peripheral edge formed by fusion of the dorsal and ventral sclerites. Care was taken to clip the exoskeleton deeply enough to sever the wing bases, yet preventing damage to the internal organs. After trimming, the specimen was embedded in warm wax and covered with 70% ethanol. The scutellum was then removed by flexing it forward and pulling it outward. A similar procedure was used to free the pronotum. The tergum was removed by lifting its posterior edge up and forward. To expose the head capsule and its contents, the dorsal sclerites of the cranium were fragmented with forceps and removed in sections.

RESULTS

The alimentary canal of *B. quadripustulata* consists of a pharynx, esophagus, ventriculus divided into four regions, pylorus with paired malpighian tubules, rectum, and associated salivary structures.

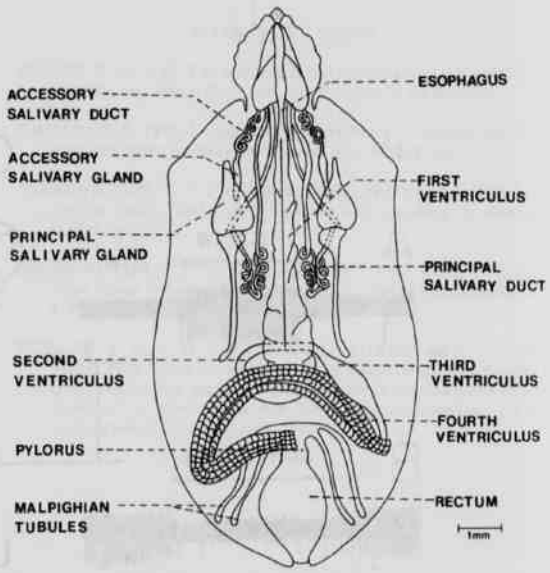

Figure 1. Dorsal View of the Alimentary Canal of *Brochymena quadripustulata*.

The esophagus consists of a long semi-transparent tube which extends from the anterior portion of the head passing between the circumesophageal connectives to approximately the middle of the prothorax (Fig. 1). The esophagus opens posteriorly into the ventriculus.

The ventriculus is divided into four distinct regions. Each region differs in length and contour. The first ventriculus appears as a large empty elongate sac which is thin walled with a rugose surface bearing a prominent dorsal raphe (Fig. 1). Specimens dissected *in vitro* under insect Ringer's exhibited peristaltic waves in this region. The second ventriculus follows as a long slender tube deflecting dorsally and then anteriorly to pass ventrally beneath the posterior region of the first ventriculus (Fig. 1). A gradual enlargement grades into the third ventriculus which appears to be the shortest region of the alimentary canal of *B. quadripustulata* (Fig. 2). It is a bulbous structure which constricts posteriorly to join the fourth ventriculus, composed of a tubular structure surrounded by four rows of gastric caecae arranged

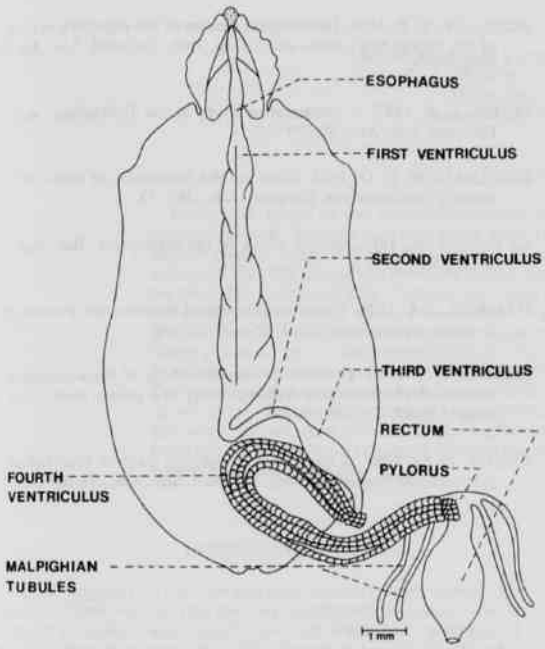

Figure 2. Dorsal View of the Alimentary Canal of *Brochymena quadripustulata* with Salivary Apparatus Removed and Parts Extended.

along its entire length (Fig. 1,2). The fourth ventriculus coils within the abdominal cavity and lies dorsally above the pyloric region with its posterior end connecting laterally to the pylorus (Fig. 1). Gastric caecae obscure this ventriculus from view (Fig. 1,2). The gastric caecae appear as uniform, sac-like structures which are closely set together.

The pylorus provides for attachment of the fourth ventriculus as well as for insertion of the malpighian tubules. It appears as a rounded knob-like structure with a pair of malpighian tubules attaching at each side of its anterior end (Fig. 1,2). The malpighian tubules float freely with the lower abdomen with some entwining around the ventricular regions before ending blindly. The posterior end of the pylorus constricts slightly at its juncture with the rectum.

The rectum is the posterior-most portion of the alimentary canal terminating with the anal opening. The rectal sac is a membranous structure which is dilated in the middle and then abruptly tapers into the anus (Fig. 1,2). The rectum was found to vary in size and shape from a small oval sac to an enlarged heart-shaped sac depending upon the amount of fluid it contained.

The associated salivary structures consist of principal and accessory glands and ducts. The two principal salivary glands are unequally bilobed and lie dorsad to the ventriculus in the thorax, the posterior lobes extending into the abdomen (Fig. 1). Each principal gland is provided with an accessory gland lying laterad and emptying by means of a long duct which extends into the head capsule. The duct retroverts into the abdomen, is directed anteriorly, undergoes a series of convolutions and finally opens at the juncture of the two lobes of the principal salivary gland (Fig. 1).

DISCUSSION

The typical hemipteran alimentary canal pattern was found to exist for *B. quadripustulata*. Comparison of this structure in other species of Pentatomidae and other selected Hemiptera resulted in similar anatomical patterns with the ventriculus comprising the largest part of the alimentary canal.

Since delineation of the pharynx and the esophagus was not anatomically feasible without histological investigation, the esophagus was chosen as the originating structure for this study of the alimentary canal as was also the case in the studies of Kurup (1963) and Ahmad and Afzal (1978). The tubular esophagus of *B. quadripustulata* was found to be moderately long gradually grading into the ventriculus. Studies by Hamner (1936), Harris (1936) and Breakey (1936) reported similar results while Ahmad and Afzal (1978) described an esophagus which terminated with an enlarged bulbous portion before passing into the first ventriculus. Studies by Ahmad and Afzal (1978) revealed the first ventriculus to consist of a small spherical anterior portion constricting to form a larger posterior suboval sac. No definite constriction was observed in *B. quadripustulata* which was found to be similar in structure to that of the coreid, *A. tristis* (Breakey, 1936).

The second ventriculus of *B. quadripustulata* was found to be relatively short, failing to comprise one-half the length of the alimentary canal as reported for *C. patricius* by Kurup (1963). In the specimens of *B. quadripustulata* studied, the majority had entered dipause and contained little or no food residue, thus the second ventriculus failed to display extensive dilation as reported by Breakey (1936) and Harris (1936).

According to Harris (1936), the third ventriculus is not a distinct region but regarded as a part of the second ventriculus because of the simimlarities of their histologies. However, Kurup (1963) regards the two regions as being distinct. In *B. quadripustulata*, an anatomical distinction between the two regions of the ventriculus appears to exist (Fig. 2), although no histological studies have been made to verify this.

The fourth ventriculus of *B. quadripustulata* appeared tubular bearing four rows of gastric caecae. The caecae have been studied in detail by Glasgow (1914) who found them to contain organisms which inhibit the growth of foreign bacteria in the mid-intestine. According to Elson (1937), the presence or absence of gastric caecae bears great importance from both a phylogenetic and nutritional point of view. *L. trivittalus*, a species which feeds chiefly on plants but occassionally on the fluids of animals, lacks gastric caecae (Glasgow, 1914). However, Breakey (1936) observed *A. tristis*, a strictly phytosuccivorous species, as having well-developed caecae arranged in two rows of closely set diverticula, whereas *B. quadripustulata* and all other species of pentatomids referred to in this study possessed four rows of gastric caecae.

The pylorus of *B. quadripustulata* compared favorably to that of *S. pugnax* (Hamner, 1936) yet differed from descriptions reported by Kurup (1963), Ahmad and Afzal (1978) and Breakey (1936). The malpighian tubules of *B. quadripustulata* were found to occupy the posterior portion of the abdominal cavity whereas Breakey (1936) described the tubules of *A. tristis* as extending into the caudal portion of the abdomen above the alimentary canal.

The rectum of *B. quadripustulata* was found to be consistent in structure with rectal sacs of other species of pentatomids and hemipterans; the anterior end of the rectum being formed by an extension of the pylorus and the posterior end tapering to form the anus.

The salivary glands of phytosuccivorous species may be differentiated in a general way from other groups by their complexity (Elson, 1937). The principal salivary glands studied in *B. quadripustulata* appeared as unequal bilobed structures, as was found in the studies of Ahmad and Afzal (1978) and Harris (1936).

The anterior lobes of the principal salivary glands in *B. quadripustulata* are broad based and extend anteriorly while the posterior lobes are tail-like and taper posteriorly ending bluntly. Hamner (1936), however, found the principal salivary glands of *S. pugnax* to have anterior lobes somewhat hand-shaped with four distinct finger-like projections on the anterior end. In many species, the principal salivary glands may be divided into several lobes or take on the appearance of clusters of grapes as reported by Elson (1937).

In insects which possess accessory salivary glands, a pair of ducts leads from the juncture of the two lobes of the principal glands; one duct leading to the accessory gland and the other to the salivary pump. This condition was observed in *B. quadripustulata*. Studies by Ahmad and Afzal (1978), Harris (1936), Hamner (1936) and Breakey (1937) also reported a comparable arrangement of the accessory glands and ducts.

ACKNOWLEDGMENTS

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MERCURY CONTENT OF WATERS IN THE MIDCONTINENT REGION

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ABSTRACT

Two major areas of the midcontinent region were investigated for their aqueous mercury concentrations. Sixteen surface water and 17 ground water samples were collected in an eleven county area of N.W. Arkansas, S.W. Missouri and N.E. Oklahoma (Ozark area) and analyzed for total dissolved mercury by the flameless atomic absorption spectrophotometric method. The range (<0.2 to 0.8 ppb), the mean (0.4 ppb) and the median (0.4 ppb) are the same for both ground water and surface water. Values obtained for the Ozark area are slightly greater than those reported for surface water by others (about 0.1 ppb), but are well within the range reported for surface waters (0.1 to 17.0 ppb). The range for 102 ground water samples from the Ouachita Mountain area is <0.1 to 2.3 ppb, the mean 0.3 ppb and the median 0.1 ppb. Thus, the mercury values for this area are similar to those of the Ozark area except for a higher upper range. The mercury mineralization (cinnabar) in the southern part of the Ouachita Mountain area, in part, is the cause of the higher values. Only two samples (2.1 and 2.3 ppb), both from the Ouachita Mountain area, exceed the EPA drinking water limits of 2 ppb mercury in the western Arkansas region.

INTRODUCTION

Eh-pH diagrams for aqueous inorganic mercury under natural surface conditions indicate that the only significantly abundant form of mercury is undissociated metallic mercury which has a solubility of about 25 ppb. In waters with a high chloride concentration the solubility of mercury may be greatly increased by the formation of chloride complexes. In addition, much of the mercury in natural waters occurs as soluble organic complexes such as methylmercury, $CH_3\ Hg^+$ or dimethylmercury $(CH_3)_2$ Hg. Under reducing conditions, mercury may be precipitated as the insoluble sulfide, HgS_2, lowering mercury concentration in solutions (Hem, 1970). The affinity of mercury for sorption and complexing reactions with suspended particulate material results in the metal being effectively removed from solution (Hinkle and Learned, 1969). Because of these reactions, natural waters generally contain extremely low concentrations of mercury (Wershaw, 1970; Jenne, 1970). Surface waters, except where they have been influenced by special geological conditions or man-made pollution, generally contain less than 0.1 ppb mercury but concentrations can range much higher. Higher concentrations are likely to occur in underground waters because of the longer and more intimate contact with mineral grains and other environmental factors (U.S.G.S., 1970).

GEOLOGIC SETTING

Two areas of the midcontinent region, the Ozark study area and the Ouachita Mountain area, have been investigated to determine background aqueous mercury concentrations. The Ozark study area includes most of the northwestern corner of Arkansas, and small parts of southwestern Missouri and northeastern Oklahoma (Fig. 1). Agriculture and forestry are the major industries of the Ozark area, which is located primarily within the Boston Mountains, and the more gentle relief Springfield and Salem Plateaus. The predominant rocks of this area are limestone, sandstone and shale which are primarily of Mississippian and Pennsylvanian age with only a small amount of Ordovician strata. Sedimentary rocks generally average less than 100 ppb mercury and seldom exceed 200 ppb except for certain organic rich shales (U.S.G.S., 1970). Localized lead and zinc mineralization and several coal deposits in the Ozark area could contain at least 100 ppb of mercury. Based on the mercury content of the rocks of the area, the background levels of aqueous mercury would be expected to be low.

The Ouachita Mountain area is 135 × 103 km. The northern part encompasses the core of the Ouachita Mountains and the southern part includes the Athens Plateau and some of the Gulf Coastal Plains (Fig. 2). The area is largely farm or National Forest lands. In the northern part of the Ouachita Mountain area shales, Arkansas Novaculite (chert), and sandstone predominate with only minor limestone. These formations range in age from Cambrian to Carboniferous and are folded and faulted intensely. Manganese mineralization is widespread and major barite deposits occur as a result of replacement or fracture filling. Quartz veins in the area occasionally contain sphalerite (ZnS) and galena (PbS). Mercury should be associated with these sulfide deposits in minute amounts. Cretaceous limestone, gravel, siltstone and sandstone, and Quarternary gravel, sand and silt are predominate in the southern part of the area. Barite, cinnabar (HgS), and antimony mineral districts are also present. Thus, the mercury content of ground water due to the rocks and sediments would be expected to be low, except in the cinnabar mineralized district.

METHODS AND MATERIALS

Thirty-three samples, including 16 surface water and 17 ground water samples, were collected in the Ozark study area during the period from June, 1978 to June, 1979 (Table 1). The distribution of the sample sites is shown in Fig. 1. The samples were collected within a 50 mile (km) radius of Gentry, Arkansas, to serve as background data for further studies concerned with the coal-fired electric plant located there. The distribution of the 102 ground water samples of the Ouachita Mountain area are shown in Fig. 2. Wagner et al., (1980) have reported on the water chemistry of these samples.

Each sample was filtered through a 0.45 micron membrane filter, placed in a clean polyethylene container and acidified with 1:1 nitric acid (3 ml of acid per liter of water). The samples were returned to the laboratory and mercury was determined by atomic absorption spectrophotometry using the flameless method.

All collection and analytical methods were those recommended by EPA (1974). This analytical method measures total dissolved mercury (both organic and inorganic species). The limit of detection of mercury based on the above techniques was 0.1 to 0.2 ppb.

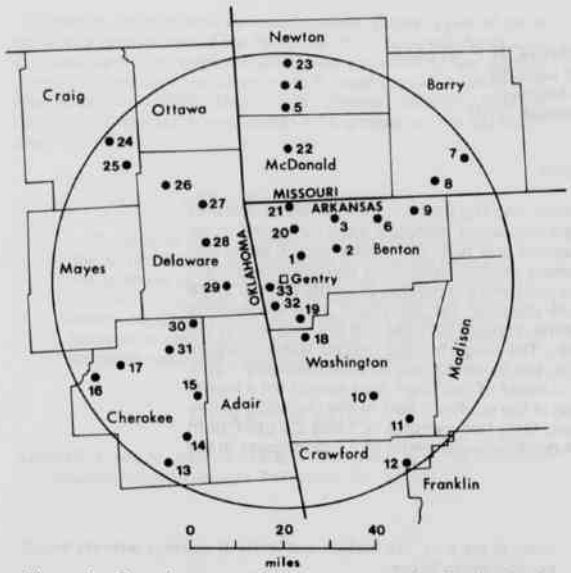

Figure 1. Ground water and stream water sample distribution for the Ozark area. See Table 2 for data.

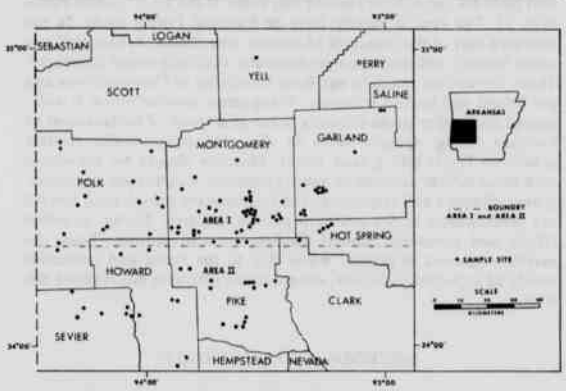

Figure 2. Ground water sample distribution for the Ouachita Mountain area. After Wagner and Steele, 1980.

RESULTS AND CONCLUSIONS

The results of this investigation indicate that the mercury content of waters in the midcontinent region is well below the recommended 2.0 ppb limit set for drinking water by the U.S. Environmental Protection Agency (1976) except for two samples (2.1 and 2.3 ppb) in the Ouachita area. Of the 33 Ozark-area samples, only 6 had concentrations greater than 0.5 ppb mercury. The mean and median values for the groundwater samples were both 0.4 ppb, and the stream water samples had the same values (Table 1). The ranges for the ground water and stream samples were both from less than 0.2 to 0.8 ppb (Table 2). Several of the high values for the Ozark area may be the result of unusual situations or contamination. Sample number 16, a well which had a mercury concentration of 0.8 ppb, had been subjected to regular treatment with chlorine bleach and had been treated the day the sample was collected. Therefore mecuric chloride complexes may have increased the mercury concentration or the bleach may have contaminated the water with mercury because mercury is used in the manufacture of bleach. Another well, sample number 29, had a concentration of 0.7 ppb and contained significant rust. Iron oxide colloids may have sorbed mercury with some having passed through the filter. Stream water sample 22 was collected after a rain from a small stream flowing between a major highway and a railroad track and contained 0.8 ppb mercury.

Although the Ouachita Mountain area has a higher upper range (2.3 ppb) than the Ozark area (0.8 ppb) most of the values of the two areas are similar as indicated by the means and medians (Table 1). Only five samples in the Ouachita Mountain area exceed 1.0 ppb mercury. The generally higher mercury values in the southern part of the Ouachita Mountain area appear to be associated, at least in part, with the mercury mineralization. The four samples collected from the mercury district range from 0.6 to 2.3 ppb mercury, and a greater percentage (42%) of the samples in the southern part of the area exceed 0.5 ppb mercury, than in the northern part (15%). No correlation is readily apparent between mercury concentration and sample areal distribution, well depth, stream flow, rock type or mineralization except for the cinnabar deposits. Finally, all the values fall within the range of normal background concentrations, and are similar to those reported by others (Table 1).

ACKNOWLEDGEMENTS

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Table 1. Comparison of mercury concentrations of ground and surface waters.

Location	Number of Samples	ppb Range	ppb Mean	ppb Median
Ground Water				
Ozark Area	17	<0.2-0.8	0.4	0.4
Washington Co., Ark.[a]	5	0.1-0.2	0.1	0.1
Ouachita Mtn. Area[b]	102	<0.1-2.3	0.3	0.1
Joplin, MO[c]	37	<0.1	<0.1	<0.1
Front Range, CO[d]	49	-	1.1*	-
Surface Water				
Ozark Area	16	<0.2-0.8	0.4	0.4
Washington Co., AR[a]	2	0.1-0.3	0.2	-
Joplin, MO[c]	15	<0.1	<0.1	<0.1
S. Carolina[e]	27	<0.2-0.3	<0.2	<0.2
Adirondacks, NY[f]	39	<0.5	<0.5	<0.5
U.S.A.[g]	73	<0.1-17.0	0.9	0.1

*geometric mean for uncontaminated samples

[a]Coughlin (1971)
[b]Wagner et al. (1980)
[c]Proctor et al. (1976)
[d]Klusman (1977)
[e]Abernathy (1979)
[f]Buller (1950)
[g]Wershaw (1970)

Table 2. Sample location, type and mercury concentration for the Ozark Area. GW = ground water and SW = stream water.

Sample	State	County	Description	Type	Concentration, ppb
1	Arkansas	Benton	NE¼ SE¼, Sec. 23, T21N R33W	GW	0.8
2	Arkansas	Benton	NE¼ SW¼, Sec. 11, T21N R32W	GW	0.6
3	Arkansas	Benton	SW¼ SE¼, Sec. 3, T22N R32W	GW	0.3
4	Missouri	Newton	SW¼ SW¼, Sec. 20, T29N R31W	SW	0.7
5	Missouri	Newton	NE¼ NE¼, Sec. 29, T27N R32W	GW	0.4
6	Arkansas	Benton	NE¼ NW¼, Sec. 26, T22N R31W	SW	0.5
7	Missouri	Barry	NW¼ NW¼, Sec. 25, T25N R28W	GW	0.3
8	Missouri	Barry	SW¼ SW¼, Sec. 22, T24N R28W	SW	0.5
9	Arkansas	Benton	NE¼ SE¼, Sec. 21, T23N R29W	GW	0.3
10	Arkansas	Washington	SE¼ SW¼, Sec. 6, T16N R30W	SW	0.5
11	Arkansas	Washington	NE¼ SW¼, Sec. 3, T15N R29W	GW	<0.2
12	Arkansas	Crawford	SW¼ SE¼, Sec. 13, T14N R29W	SW	0.3
13	Oklahoma	Cherokee	NE¼ SW¼, Sec. 28, T17N R22E	SW	0.2
14	Oklahoma	Cherokee	NW¼ SW¼, Sec. 22, T15N R23E	SW	0.4
15	Oklahoma	Cherokee	SW¼ NE¼, Sec. 27, T17N R23E	SW	0.2
16	Oklahoma	Cherokee	NW¼ SW¼, Sec. 8, T17N R20E	GW	0.8
17	Oklahoma	Cherokee	NW¼ NE¼, Sec. 16, T17N R20E	SW	0.4
18	Arkansas	Washington	NW¼ NW¼, Sec. 6, T18N R32W	GW	<0.2
19	Arkansas	Benton	NE¼ SW¼, Sec. 7, T19N R32W	SW	0.5
20	Arkansas	Benton	SW¼ NE¼, Sec. 24, T22N R33W	SW	0.2
21	Arkansas	Benton	NE¼ SE¼, Sec. 23, T23N R33W	GW	<0.2
22	Missouri	McDonald	NW¼ SE¼, Sec. 19, T26N R32W	SW	0.8
23	Missouri	Newton	NW¼ SE¼, Sec. 7, T29N R31W	GW	<0.2
24	Oklahoma	Craig	SE¼ NW¼, Sec. 7, T26N R21E	SW	0.4
25	Oklahoma	Craig	SE¼ SE¼, Sec. 27, T26N R21E	GW	0.2
26	Oklahoma	Delaware	SE¼ NW¼, Sec. 22, T25N R22E	SW	0.2
27	Oklahoma	Delaware	NE¼ SW¼, Sec. 19, T23N R24E	GW	<0.2
28	Oklahoma	Delaware	SE¼ NW¼, Sec. 24, T22N R23E	SW	<0.2
29	Oklahoma	Delaware	SW¼ NW¼, Sec. 9, T20N R24E	GW	0.7
30	Oklahoma	Cherokee	NW¼ SE¼, Sec. 14, T19N R23E	SW	<0.2
31	Oklahoma	Cherokee	SE¼ NW¼, Sec. 7, T18N R23E	GW	0.2
32	Arkansas	Benton	NW¼ SE¼, Sec. 6, T20N R33W	GW	0.3
33	Arkansas	Benton	NW¼ SW¼, Sec. 24, T20N R34W	SW	<0.2

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AN INVENTORY OF THE DECAPOD CRUSTACEANS (CRAYFISHES AND SHRIMPS) OF ARKANSAS WITH A DISCUSSION OF THEIR HABITATS

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ABSTRACT

The freshwater decapod crustaceans of Arkansas presently consist of two species of shrimps and 51 taxa of crayfishes divided into 47 species and four subspecies. The shrimps are represented by *Macrobranchium ohione* and *Palaemonetes kadiakensis*. The crayfish fauna is the largest of any state west of the Mississippi River reflecting the variety of habitats within Arkansas as a result of the geologic diversity in the state. The Ozark Plateaus and Ouachita provinces are dominated by the genus *Orconectes*, while in the Gulf Coastal Plain *Procambarus* is the most conspicuous group. Other crayfish stocks present include *Cambarus*, found predominantly in the Ozark Plateaus province, and *Bouchardina*, *Cambarellus*, *Fallicambarus*, and *Faxonella* which are largely restricted to the Coastal Plain. The crayfishes and shrimps live in a broad array of epigean lotic and lentic habitats. In addition, a troglobitic crayfish occupies limestone solution channels, and burrowing crayfishes inhabit the subsurface water table. General discussions of the taxonomy and geographic distributions of the genera are presented, including brief descriptions of habitats in Arkansas that are utilized by freshwater decapods. Only the conservation of a single species, the troglobitic crayfish *Cambarus zophonastes*, is of concern in the state.

INTRODUCTION

Fourteen species of shrimps in four genera (two families) are native to the continental United States; the crayfish fauna consists of 284 species and subspecies divided among ten genera (two families). Shrimps, along with crabs, dominate the freshwater decapod fauna in tropical regions of the world, while crayfishes are limited mostly to the temperate areas. Of the few species of shrimps that are endemic to or range into north temperate regions of the western hemisphere, two are known from Arkansas. The larger *Macrobranchium ohione* (up to 102 mm long, Holthuis, 1952) was the basis of formerly more extensive food and bait fisheries in the Mississippi River drainage (Hedgpeth, 1949). This fishery is still carried out in Louisiana (Huner, 1979). The smaller *Palaemonetes kadiakensis* (up to 53 mm, Holthuis, 1952, but typically much less) is also utilized for fish bait as well as for fish forage in farm ponds. It is this latter use that may have contributed to the transplantation of its closest relative *P. paludosus* (historically found east of the Appalachians) into portions of neighboring Mississippi, Louisiana, Texas, and Oklahoma. Finding *P. paludosus* in Arkansas would not be surprising.

More species of crayfishes inhabit Arkansas waters than any other state west of the Mississippi River (51 taxa consisting of 47 species and 4 subspecies, see Table 1). Only Georgia (Hobbs, in press), Alabama, and Tennessee (Bouchard, 1976b) are presently known to support more species. Factors which seem to contribute to large assemblages of crayfishes are a diversity of habitats within or in close proximity to areas of primary or secondary evolution of various groups, a sufficiently long geological history of favorable climates and habitats, lack of competition from more advanced groups of decapod crustaceans, and the presence of stocks that are ecologically very successful in their utilization of diverse habitats.

The crayfishes and shrimps will be examined here by presenting first, brief discussions of some structures that are important in their taxonomies, including pertinent literature; second, a general review of decapod ecology and the aquatic habitats that are utilized by them in Arkansas, including collecting techniques, and third, a discussion of the state's fauna.

TAXONOMY

The classification of shrimps that occur in the United States is based upon several morphological characteristics (see Holthuis, 1952 and Chace, 1959). In shrimps, as in many other arthropod groups, the secondary sexual structures utilized in copulation are morphologically more static than others that traditionally have been used in taxonomy and, most importantly, are less reflective of or influenced by the environment of the animal. Such structures in adult males, namely the setal pattern of the appendix masculina of the second pair of pleopods (=appendages of the abdomen), have proven to be beneficial in the identification of shrimps (see Hobbs, 1968; Chace and Hobbs, 1969; Fleming, 1969; Villalobos and Hobbs, 1974; and Strenth, 1976).

The taxonomy of North American crayfishes also is based upon numerous morphological characteristics (see Hobbs, 1972b), the secondary sexual ones being of primary importance, such as the annulus ventralis, copulatory hooks, bosses on the coxae of some pereiopods (=walking legs) (all limited to the Cambaridae), and first pleopods. The morphology of the male first pleopods is the single most important character in identifying most of the species and practically all of the genera of North American crayfishes. The locations of the secondary sexual structures are noted in Crocker and Barr (1968) and Hobbs (1972a). Most taxonomic keys to the eastern North American crayfish family Cambaridae rely upon the morphology of the first pleopods on the first form, or form I male. In the Cambaridae, adult males exhibit two morphological forms, molting into these conditions with only the first form capable of breeding, the second form, or form II, being sexually nonfunctional. The gonopod of the form I male with its more delicate, finely sculptured elements, at least one of which consists of amber, corneous material, is easily distinguished from the form II gonopod with elements usually reduced in length and/or more inflated and without a corneous deposit (see Hobbs, 1972b). The remaining secondary sexual structures in the form II male are reduced in size and/or sculpture, including a noticeable reduction in the size of the chelae (=first pair of pereiopods). Figures 1 and 2 show some of the morphological variety in the form I

male first pleopods in the North American cambarid genera including also the first pleopod of *Pacifastacus*, a genus found almost entirely west of the continental divide and the only representative of the North American Astacidae. The astacids do not exhibit an alternation of sexual morphological forms. Hobbs' Key (1972b) and Checklist (1974) to the North and Middle American crayfishes together form the foundation for the study and identification of these animals and include numerous drawings of most of the species with accounts of their ranges and general habitats.

The cornerstone of any examination of Arkansas crayfishes is Williams' (1954) study of the crayfishes of the Ozark Plateaus and Ouachita provinces. Reimer (1963) has provided an unpublished survey of the crayfishes of Arkansas which is also of great assistance in identifying and studying the state's fauna. A recent 1978) general examination of the fisheries (Huner); life histories (Payne); trophic relationships (Lorman and Magnuson); and taxonomy, distribution, and general ecology (Bouchard) of crayfishes has appeared in the *Bulletin of the American Fisheries Society* (*Fisheries*, vol. 3, no. 6). In addition to general information on crayfishes, all of the above references provide numerous citations that examine various aspects of the biology and distribution of crayfishes in depth.

GENERAL ECOLOGY

Freshwater decapod crustaceans can be grouped into three broad, overlapping, ecological categories. There are those species that inhabit the diverse surface water habitats (epigeaners), those species that utilize underground solution channels in limestone regions (cavernicoles), and those species (in the United States crayfishes only) that burrow into the subsurface water table (burrowers). Since these categories are by no means rigid, there is some overlap among the groups. For example, crayfishes that occupy surface water follow or attempt to follow a receding water table by burrowing; those that spend most of their lives in subsurface tunnels may leave their burrows during the breeding season or to feed or to disperse, sometimes entering surface waters, and cavernicoles may be washed or wander from caves or spring sources. Inasmuch as crayfishes and shrimps are negatively phototropic, epigean species do not hesitate to enter caves. Any decapod crustacean could be a visitor to subterranean waters (=trogloxene), and therefore any epigean species that finds the stenothermal habitat near or in a spring source a congenial residence could enter the subterranean waters. Cave crayfishes have been found by one of us (RWB) to be living among the gravel and

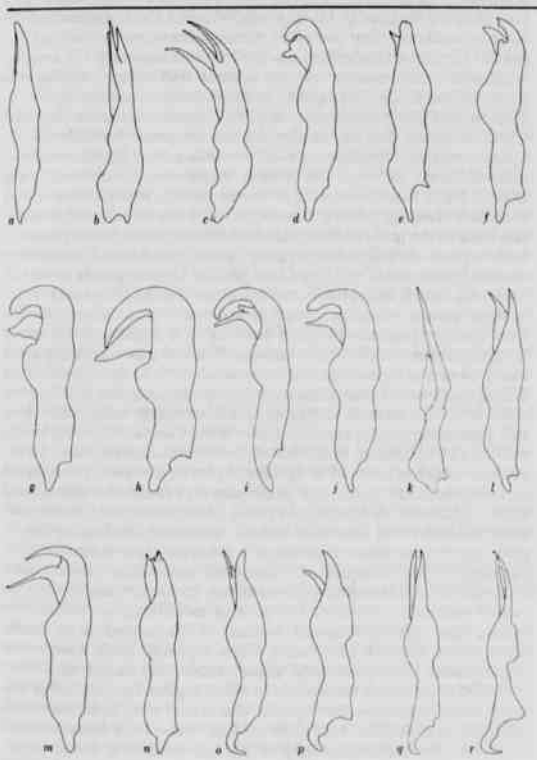

Figure 1. (Caudal (k) and lateral views of left first pleopod in nine genera of crayfishes (a, Astacidae; b-r, reproductive form in Cambaridae). *a, Pacifastacus gambelii; b, Cambarellus shufeldtii; c, C. alvarezi; d, Barbicambarus cornutus; e, Bouchardina robisoni; f, Cambarus pristinus; g, C. bartonii; h, C. conasaugaensis; i, Fallicambarus macneesei; j, F. oryktes; k, Faxonella clypeata; l, Hobbseus orconectoides; m, H. prominens; n, Orconectes a. australis; o, O. limosus; p, O. difficilis; q, O. propinquus; r, O. rusticus* (from Hobbs, 1974, 1977).

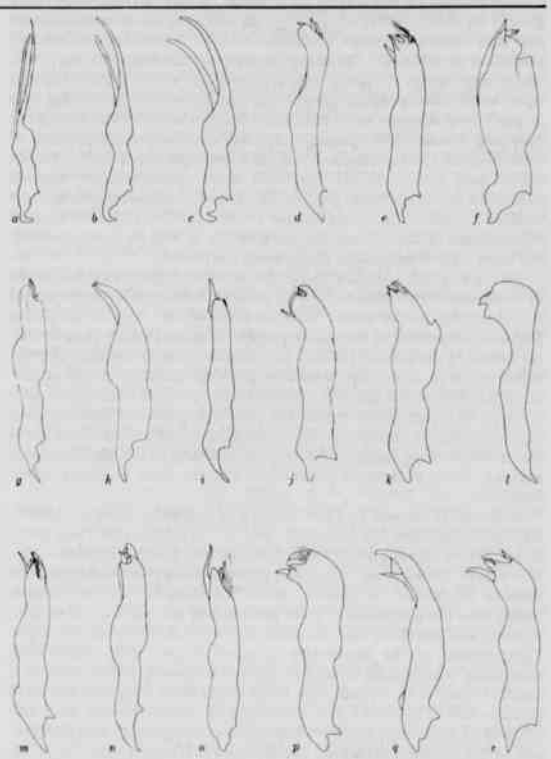

Figure 2. Lateral view of left first pleopod in three genera of crayfishes (reproductive form in Cambaridae). *a, O. putnami; b, O. virilis, c, O. p. palmeri; d, Procambarus geodytes; e, P. a. acutus; f, P. cubensis rivalis; g, P. tulanei; h, P. hinei; i, P. teziutlanensis; j, P. gonopodocristatus; k, P. howellae; l, P. truculentus; m, P. spiculifer; n, P. bouvieri; o, P. alleni; p, P. pearsei; q, P. tenuis; r, Troglocambarus maclanei* (from Hobbs, 1974).

rocks at spring sources, utilizing the more abundant epigean resources in the absence of, or with reduced competition from, epigean species. Many crayfishes frequenting cave habitats are facultative species (=troglophiles) (although none in Arkansas are) and commonly live in both cave and surface waters, especially those that are influenced by spring sources. Some cave crayfishes that are known only from spelean habitats (*viz.* the crayfish *Cambarus nerterius*) do not bear the well-developed morphological adaptations to their spelean environment as do highly specialized troglobites (loss of pigment; very reduced eyes; long, thin appendages; reduced body size). The troglophiles and less modified troglobites probably represent transitional phases through initial physiological and behavioral adaptations toward becoming highly adapted to compete in and more efficiently utilize the spelean environment. There are no troglobitic shrimps known from the limestone regions of the Salem and Springfield plateaus of the Ozark Plateaus province, although they are present in cave systems of the Interior Low Plateaus province to the northeast and the Edwards Plateau to the southwest. The discovery of a troglobitic shrimp in the Salem and Springfield plateaus region in Arkansas or Missouri would not be surprising.

The burrowing crayfishes have been further divided into three groups by Hobbs (1942) depending on their degree of specialization and how closely they are identified to their burrowing habitat and classified as follows: "primary burrowers (restricted to burrows); secondary burrowers (generally occupy burrows but wandering into open water during rainy seasons); tertiary burrowers burrowing only in periods of drought or occasionally but not necessarily, during the breeding season)." Morphological modifications and adaptations of burrowers to their subsurface habitat have been discussed by Hobbs (1976) and Bouchard (1978a). The most apparent modifications exhibited by burrowers include (i) broad, depressed chelae, (ii) vaulted carapace, (iii) long, narrow areola, and (iv) abdomen and tail fan reduced in size. These characteristics, as well as several others, are most well-developed in the primary burrowers.

A major factor contributing to the adverse epigean crayfish fauna in Arkansas is the wide variety of habitats which reflects the varied physiography of the state. Here streams mirror the chemical and physical properties of the physiographic region(s) which they drain. As noted by Bouchard (1976a) the ranges of many species of crayfishes occur in or are delineated by physiographic provinces or sections thereof, and a species is more likely to cross (actively or passively) a drainage divide within the physiographic unit than to move into an adjacent region. However, crayfish distributions often bleed into a neighboring region reflecting the blending of the physiographic regions. These peripheral populations usually occur in smaller numbers.

Arkansas is crossed by three broad physiographic units as follows: (i) Ozark Plateaus, (ii) Ouachita, and (iii) Gulf Coastal Plain provinces. These regions are further divisible into a number of sections. The Ozark Plateaus and Ouachita provinces together constitute the Interior Highlands, or uplands, while the Coastal Plain province is considered the lowlands. It is the presence of extensive areas of both uplands and lowlands that enriches the biotic diversity of Arkansas. Comparisons of the freshwater decapod faunas with neighboring Louisiana, which lacks upland areas, and Missouri, which has only a small lowland area, reveals that those states have, respectively, 40 (4 shrimps and 31 species and 5 subspecies of crayfishes) and 30 (2 and 28) taxa of decapods. Since no discussion of the geology and topography of the region is presented herein, the reader is referred for physical descriptions and/or maps of the region to Fenneman (1938), Thornbury (1965), Foti (1974), and Haley (1976).

DECAPOD HABITATS

There are obvious faunal differences between the Gulf Coastal Plain and Interior Highlands that relate to the contrasting physical makeup of the two regions. The Interior Highlands are dominated by the typically upland genus *Orconectes*, with shrimp present but rare, while in the Gulf Coastal Plain *Procambarus* is the most conspicuous crayfish group. The genera *Bouchardina*, *Cambarellus*, and *Faxonella* are limited almost entirely to this latter region, and the shrimps, especially *P. kadiakensis*, are a noticeable faunal component. The obvious differences between the aquatic habitats of the two regions include lower stream gradients and greater abundance of lentic habitats in the Coastal Plain. The larger area of standing water here, in part seasonal, and less rapid surface runoff and subsurface drainage is due to soil characteristics, the subdued topography, and generally less entrenched streams and rivers. In terrestrial, marshy, swampy, or other lentic and lotic areas, various degrees of leaching of tannins and lignins from the decaying vegetation occur and impart a characteristic coffee or tea color to the water. In addition, many lotic environments are subject to seasonal fluctuations in water levels, and during periods of low flow the water may darken considerably with derived constituents from leaf and brush litter in the stream. We should not, however, like to leave the impression that all Coastal Plain streams are stained. Small streams or waters fed by at least moderately large spring sources reflect the clear water that issues into them while most of the unaltered Coastal Plain streams with at least a moderate flow are clear. Even some streams draining the gentler terrain of Quaternary age are at least seasonally so. Another noticeable characteristic of the streams and rivers crossing the Coastal Plain is that they tend to be siltier than those crossing the upland areas. Additionally, below the Fall Line zone the more abundant lentic or slowly flowing waters provide congenial habitats for the colonization and proliferation of a conspicuous aquatic vascular plant element, although this flora is by no means restricted to the Coastal Plain. *Justicia americana* (water willow), with its thick, tough roots and creeping growth, is a species that is well-adapted to maintain itself in the gravel substrates of moderately swift flowing areas of both regions. *Nasturtium officinale* (water cress) and *Podostemum ceratophyllum* (river weed) are conspicuous aquatic plants of the uplands, the former being limited to limestone regions. *Nuphar* (spatterdock or yellow water lily), another noticeable plant above the Fall Line zone, is common in lentic habitats as is typical of the family Nymphaeaceae (water lilies), but seems out of place growing along rocky stream margins near the current where it is also found. Even during that time of year when its leaves are lacking, the thick, green roots with their pattern of petiole and flower stalk scars make them still quite prominent in shallow water. In the Coastal Plain *Nuphar*, as well as the remaining members of the Nymphaeaceae, are, as expected, common here. Most species of plants, however, are adapted to lentic habitats which are much more abundant in the Coastal Plain. Additional conspicuous aquatic plants, which are more common below the Fall Line zone but not necessarily limited to this region, are *Potamogeton* (pondweed), *Myriophyllum* (water milfoil), *Ludwigia* (false loosestrife), *Vallisneria americana* (tape grass), *Utricularia* (bladderwort), *Ceratophyllum* (coontail), and *Callitriche* (water starwort), the latter often being as striking in Costal Plain springs and spring-influenced habitats as *Nasturtium* is in similar areas above the Fall Line zone. These typically lentic species are opportunistic colonizers, and some utilize backwaters and other sheltered areas out of the current in either region. In these softer and more stable substrates the vascular plants may vary from only small marginal populations, especially in lotic waters, to abundant and thick growths often consisting of several species in lentic areas. These thick growths provide excellent habitat for crayfishes and shrimps.

Lithological differences are also obvious and are best exposed in the substrates of streams. In the Coastal Plain, where there is a lack of well-indurated deposits, the substrates consist mostly of unconsolidated sands, gravels, clays, and muds. There is a conspicuous absence of the rock litter habitats, so characteristic of the upland streams, that provide the favored shelter for the dominant crayfishes

of that region. Crayfishes, therefore, in the Coastal Plain rely heavily upon shelter provided by vegetation, both living and dead.

Aquatic habitats in the Coastal Plain have not been as thoroughly sampled for crayfishes as the upland areas have been due to the darkly stained waters in some places that limit visibility and/or soft substrates that lack the conspicuous rocky haunts of upland crayfishes.

Ozark Plateaus and Ouachita Provinces: The Ozark Plateaus and Ouachita provinces constitute an upland area of mostly pre-Cretaceous, well-indurated deposits. Streams draining these areas bear several types of habitats utilized by crayfishes. These animals can be found to occupy waters ranging from the smallest mountain seepage areas *(e.g., Orconectes williamsi)* to the larger rivers *(e.g., O. eupunctus, O. longidigitus, C. hubbsi)*. There appears to be no species endemic to large streams and rivers in Arkansas as is *Barbicambarus cornutus* in the Green River system of Kentucky and Tennessee. This species is found in rapidly flowing water under large limestone slabs, and the discovery of a relative of *B. cornutus* in the larger streams and rivers in the Salem and Springfield plateaus is a distinct possibility.

Within a fluvial environment some species are common in pool or backwater areas *(e.g., O. punctimanus, O. palmeri, O. longidigitus)*, while others are more frequently found in runs or riffles *(e.g., O. acares, O. leptogonopodus, O. menae, O. eupunctus, C. hubbsi)*. The habitat in mountain seepage areas usually consists of rocks and boulders in a series of small pools and intervening cascading areas. Lifting rocks here often involves moving some very large ones. In small to large streams and rivers crayfishes are collected from under rocks, on gravel or in gravel interstices, and among inundated, thick growths of *Justicia americana* beds in pools, along stream margins and around islands. In springs and spring-influenced areas of limestone regions, thick growths of *Nasturtium officinale* provide habitat along the shore and in pools. In fact, crayfishes are commonly found in almost any thick vegetation that provides sufficient cover, including mats of algae (e.g., *Cladophora*) and the fine roots of riparian trees projecting into the water from the stream bank. The most typical crayfish habitat is under rocks, including the exposed edges of bedrock formations, where they make shallow excavations into the streambed or simply utilize the spaces created by the physiognomy of the rock(s) and substrate. Rocks or logs projecting into the water from the stream margins or shoals may conceal stream crayfishes, and during the egg laying season ovigerous females are often found here, as are members of burrowing species (e.g., *C. diogenes*). Onshore rocks or logs that are separated from the main stream by an intervening muddy or dry area but are buried into the water table also provide habitat for stream crayfishes (e.g., *O. virilis, O. meeki*) and burrowers. Above the Fall Line zone, burrows in the stream banks may be apparent, especially in areas where *O. virilis* and *O. meeki* occur, since these epigean species, as well as burrowers, do not hesitate to utilize such stream bank shelters. Those species living within a gravel substrate may be quite abundant in gravels ranging from coarse stones (e.g., *O. neglectus* and *O. ozarkae*) to fine gravel (e.g., *O. macrus, O. nana*, and *O. marchandi*). Species living in fine gravel are smaller than those that predominate in rock litter, and even in populations of the larger species that utilize available coarse gravel, the adults are generally smaller than those of the same species from areas where sufficient rock litter is available. In areas of fine gravel where the substrate has been darkened by a silt film and/or growth of diatoms, the presence of these gravel burrowing species is made conspicuous by an area of lighter colored subsurface gravel deposited by the crayfish around the opening of the burrow. Collecting these species is most easily accomplished by working one's feet down into the loose gravel and dislodging members of the population into a downstream seine or dip net. The crayfishes of the Interior Highlands living in chert and gravel-bottomed streams typically bear a variegated, stippled, rosette, or blotched pattern which blends them with the multi-hued tans and browns of the substrate.

Leaf litter or brush and leaf accumulations harbor crayfishes (e.g., *O. palmeri longimanus*), especially juveniles, and should not be overlooked, since some species find this either a favored habitat or the only one available with other species dominating the gravel or rock litter.

A seine or dip net (the D-ring type is efficient for all kinds of habitats) is commonly used for collecting crayfishes from surface streams. In the larger streams and rivers seines and dip nets are, however, limited to the shallower portions, along shore, and in backwater pools. Collecting at night with a lantern (it illuminates a larger area than a flashlight) is often productive, since crayfishes and shrimps are more likely to be found foraging in open water at this time, and in large streams at least some individuals will move into shallower water (e.g., adult *O. longidigitus*). Other collecting methods utilized in deep waters include using minnow traps baited with fresh fish or meat and snorkeling or scuba diving in areas of clear water.

Cave species are most easily collected with a dip net; one that collapses and folds is much easier to carry and negotiate through subterranean passageways. Crayfishes isolated in shallow pools are easily taken by hand. If deep water areas are present, baited minnow traps or scuba diving techniques may be used to sample these regions. The use of cheese has been observed by one of us (RWB) to be an additional effective attractant in minnow traps in these habitats, and, needless to say, very great care should be taken while exploring flooded passageways while scuba diving. The lower fecundity, longer period of maturation, and lower population densities of troglobitic species compared to their epigean relatives make these species more susceptible to overcollecting than epigean species. Collecting troglobites should therefore be judicious and reflect their abundance.

Burrowers above the Fall Line zone are found in the banks of streams, under onshore logs and rocks, in low, wet areas and high mountain seeps. They may be collected using a number of methods such as digging, fishing with a baited line, trapping with a pit or can trap, searching for them under rocks or logs in wet areas, or outside their burrows on humid evenings or after a rain storm. This latter method is by far the easiest and seems to be most productive during the wet spring months when many species become active after the winter season. Success, however, depends solely upon the unpredictable behavior of the crayfish. Searches on many rainy or humid evenings by one of us (RWB) have too often found the crayfish unobtainable in the comparative safety of the burrow entrance or the crayfish to have strayed no further than the confines of a small pool that had flooded the opening of the burrow. Finding burrowing crayfishes under onshore rocks or logs was pointed out earlier, but more often stream crayfishes are found here. In low, wet areas or high mountain seeps turning rocks or logs is a relatively easy way to collect crayfishes.

The can trap is a smaller version of the minnow trap, utilizing a large can with a piece of wire screening as the internal, apically truncate, cone-shaped funnel. The trap is baited (fresh fish or meat), and the funnel end is inserted into the ground. Pit traps are set into the ground among a population of burrowers as they are similarly employed for the capture of terrestrial arthropods. Hobbs (1972b) suggests using attractants such as meat or peanut butter in the bottom of the traps and reports the best success seems to be on warm, humid evenings.

Fishing with a line tied to a stick with a split shot and bait (fresh fish or meat) has been used successfully by one of us (RWB). A score or more of lines are set out depending on the number of fresh burrows present. The fresh chimney, which consists of excavated materials is removed, and the entrance carefully widened large enough for a hand to be thrust in. The lines are checked periodically, and when a crayfish has taken the bait it is induced to come to the surface by slowly raising the bait with the attached crayfish. If the crayfish releases the bait, it is lowered back down for it to retake. Once the crayfish has been lured to the surface, a quick thrust of the hand pins it against the burrow, and with some manipulation it is removed. If the crayfish will not come close enough to the surface to be pinned, sometimes a quick tug of the line will yank it from the burrow.

In general, however, digging the fresh burrow is usually the best available, although most laborious, method. A trowel and shovel are

carefully used while following the often complex burrow. Hobbs (1942) presents another method that he has used for many years in his collecting of burrowers. In Arkansas, *C. diogenes* is the species that is most susceptible to this method. The fresh chimney is removed, the entrance widened, and, if the burrow is not already flooded, water is poured into the hole, filling it to the top, and then vigorously roiled. If usually after several minutes, the crayfish comes to the surface to determine the source of the commotion (food?) its presence is betrayed by its antennae waving at the surface of the silty water. A quick thrust of the hand traps the crayfish before it can retreat down the burrow. I (RWB) often place a grass stem into the burrow opening, and the ascending crayfish then announces its presence by pushing up the filament.

Gulf Coastal Plain: In the Coastal Plain waters drain Cretaceous, early Tertiary, and Quaternary deposits. Here decapods occupy the complete range of surface waters from spring seepage areas and their resultant small streams *(e.g., Bouchardina robisoni* and *Faxonella clypeata)* to the higher gradient large rivers *(e.g., P. elegans* and *O. palmeri)* as well as the large, deep waters with little observable flow *(e.g., P. clarkii, O. lancifer,* and *P. kadiakensis)*. Plants are not the only organisms that are able to take advantage of areas of reduced flow in the higher gradient, larger streams and rivers. In the pool areas, along the shore, and in backwater regions additional members of *Procambarus (e.g.,* some members of *Ortmannicus* and *Pennides)* are present along with occasional members of *Faxonella* and *Cambarellus*. These latter two genera are typically abundant in shallow, isolated flood pools left by the receding waters of the main stream after periods of flooding.

It is in the largest rivers of the state, especially in the Coastal Plain, that the shrimp *M. ohione* has been collected. Seining this shrimp in open water, particularly at night, and in silty waters during the daylight hours is a productive method of collecting. This shrimp has also been taken with baited line (Hedgpeth, 1949) and commercially using slat box traps (Gunter, 1937), shrimp sets of green willow or cottonwood branches (McCormick, 1933), and bow-mounted scoops on fishing boats (Huner, 1979).

In the somewhat sluggish small- to medium-sized streams, the lentic forms become more prevalent and include again some of the burrowing species *(e.g., C. diogenes, P. curdi, P. reimeri, P. simulans,* and *P. tulanei)* and the shrimp *P. kadiakensis*.

Very small streams (about two-thirds of a meter wide or less) draining Cretaceous and Tertiary deposits are dominated by members of the genera *Faxonella, Bouchardina,* juveniles and occasional adults of some epigean *Procambarus* as well as burrowing species *(e.g., Fallicambarus hedgpethi, P. tulanei,* and *C. diogenes)* that may wander into these lotic habitats and some epigean *Procambarus*.

Lentic habitats, such as roadside ditches, borrow pits, ponds, and swampy or marshy areas, are common and often provide dense cover consisting of abundant and often luxurious growths of vascular plants and algae. These lentic areas vary from vernal pools to permanent waters where a host of species may be present *(e.g., P. viaeviridis, P. acutus, P. geminus, P. clarkii, O. lancifer, Cambarellus, Faxonella,* and *P. kadiakensis)*. Here, too, juveniles and a few adults of secondary burrowers may be found.

Epigean species that live in vernal pools or small rivulets formed from seepage areas supercharged by spring rains burrow down to the retreating water table of these habitats during drier periods thus preventing dessication. Members of the genera *Bouchardina, Cambarellus, Faxonella,* and *Procambarus* commonly live in these ephemeral pools and function as tertiary burrowers during periods of low water levels.

Crayfishes and shrimps living in the Coastal Plain utilize a wide array of shelters, as do upland crayfishes; however, without rock litter and extensive areas of large gravel crayfishes, must utilize the available, sometimes abundant, habitat provided by vegetation, both living and dead. Dead vegetation consists of logs, leaf litter in pools, or leaves that have become entrained by brush, especially along the shore. The soft, shifting sand and fine gravel substrates are ideal for lodging branches which then strain leaves from the water. The live vegetation includes the conspicuous green growths of aquatic vascular plants and algae as well as the fine roots of riparian trees protruding into the stream from a well-defined stream bank.

Burrowers are more common in and below the Fall Line zone since the soils, ranging from sandy to the moisture-retaining clays, provide a suitable medium for burrowing, especially for the construction of complex burrows. Species are found along the margins of streams and lentic waters, in spring seeps, and in low wet areas, the latter often characterized by conspicuous growths of the sedge *Juncus*. The whole range of primary through tertiary burrowers can be found in the Coastal Plain of Arkansas as follows: *C. diogenes, F. caesius, F. fodiens, F. hedgpethi, F. jeanae, F. spectrum, F. strawni, F. dissitus* (primary burrowers); *C. diogenes, F. fodiens, F. hedgpethi, P. curdi, P. reimeri, P. simulans, P. tulanei* (secondary burrowers); and *B. robisoni, C. puer, C. shufeldtii, F. blairi, F. clypeata, P. acutus, P. geminus, P. viaeviridis, P. clarkii* (tertiary burrowers).

Seines and dip nets are most often used to collect decapods in surface streams of the Coastal Plain. A gravel rake may also be employed to rake aquatic vegetation up onto the shore where careful sorting will reveal the decapods that were sheltered and/or feeding among the dense growths and/or leaf litter. Logs at or on the shore are likely to harbor some burrowing as well as epigean crayfishes, and turning or lifting these objects should not be overlooked.

Using a lantern to collect in clear water habitats or at least the shallow areas of darkly-stained waters can be productive. Minnow or lift traps (see Hobbs, 1972b) are both good methods to sample deep or very soft-botomed areas, the lift traps being more successful in silty or richly-stained waters which shield the collector from the view of the feeding crayfish. The collecting techniques for burrowers were outlined earlier in the discussion of the Ozark Plateaus and Ouachita provinces' fauna and apply here except that there are no rocks to overturn.

THE ARKANSAS DECAPOD FAUNA

Shrimps: The two species of shrimps in Arkansas include single representatives of *Macrobranchium* and *Palaemonetes*. Of the two species, *M. ohione* has been taken from the larger rivers (Mississippi, Red, and Arkansas), while *P. kadiakensis* is common in vegetation of lentic and slower moving streams as well as in the sheltered areas of more rapidly flowing environs below the Fall Line zone. One of us (RWB) has also collected this species in brush-entrained leaf litter of a medium-sized (less than 8 m wide), shallow, somewhat rapidly-flowing tributary to the Sabine River in Louisiana, so its occurrence in smaller streams in Arkansas would not be surprising. The shrimps are representatives of a more tropically disposed group. Some of these tropical shrimps *(M. acanthurus, M. carcinus,* and *M. olfersii)* range northward to warm temperate regions, especially along the Gulf Coast, with only *M. ohione* limited to and penetrating significantly into the United States (see Hedgpeth, 1949). *Palaemonetes kadiakensis* is one of three members of the genus also found in surface streams in the United States (see Strenth, 1976). Three additional species in this genus are known from subterranean waters in Texas (2 species) and Florida *(loc. cit.)*. The only other shrimps known to be restricted to or which typically inhabit freshwaters in the United States are four primitive relicts of the family Atyidae, two from surface streams in California and two from subterranean waters, one each in Alabama and Kentucky. All of these atyids are considered to be endangered, threatened, or extinct due to threats from pollution, alterations of their habitat, or altered flood regimes (see Hedgpeth, 1968 and Bouchard, 1976b; 1978b; 1980).

Crayfishes: *Bouchardina* is the most recently discovered crayfish genus and is represented by a single species, *robisoni*. It was originally known from only the type-locality, a borrow ditch backwater of a

stream-draining Eocene deposits in Lafayette County. Hobbs (1977) and Bouchard (1978c) noted that the genus in many ways resembles members of the genus *Hobbseus* from Mississippi and Alabama. Bouchard *(loc. cit.)* further noted that *Hobbseus* preferred very small streams where it is the dominant species, and that the typical habitat of *Bouchardina* may be the same. Following this assumption, recent field work has proven this to be true and the species to be more widespread, ranging through at least a four-county area of southwestern Arkansas. The species dominates the leaf litter and aquatic vegetation in these very small streams, some of which may be subject to drying. Coinhabitants include mostly juveniles of other larger species *(e.g., C. diogenes, Ortmannicus,* and *Girardiella).*

Bouchardina is one of three genera, along with *Faxonella* and *Cambarellus* native to Arkansas in which the adults are very small in size and are often overlooked by nonastacologists as being juveniles of larger species. Adult *Bouchardina* and *Cambarellus* generally display a total length of about 3 cm, while *Faxonella* is occasionally represented by slightly larger individuals.

The genus *Cambarellus,* which probably originated in the Gulf Coastal Plain, presently contains 14 species, two of which are found in Arkansas. *Cambarellus puer* and *C. shufeldtii* typically occupy lentic areas, below the Fall Line zone such as ponds, swamps, and ditches, especially small, shallow ones that are subject to drying, as well as backwater portions of streams. These two species are the only *Cambarellus* that penetrate appreciably north of the Gulf Coast area.

Only four species of the genus *Cambarus* are found in Arkansas: *C. diogenes,* a burrower; *C. hubbsi,* a stream form; *C. zophonastes,* an obligate cavernicole; and *C. causeyi,* a species that lives primarily in spring seeps where it may be found under rocks or in burrows at the higher elevations of the Boston Mountains. It is surprising that this genus is so poorly represented in the Interior Highlands with only three additional species, all troglobites, known from Missouri (two species) and Oklahoma (one species). *Cambarus,* like *Orconectes,* is a dominant component of upland habitats, primarily in the southern Appalachian Highlands to the east with which the Interior Highlands share many other faunal elements. The genus seems to have arisen on the Cumberland Plateau province in the Tennessee area. Its movement around the Mississippi Embayment portion of the Gulf Coastal Plain and its ability to colonize the Interior Highlands was in part blunted by the radiation of highly successful members of the already present genus *Orconectes.* It is surprising that more burrowing members of *Cambarus* have not been found in the uplands, since in other areas this genus has exploited the burrow habitat poorly invaded by *Orconectes.* Additional field work may uncover relatives of *C. causeyi* in seepage areas in other parts of the Boston Mountains.

The genus *Fallicambarus* probably arose on the West Gulf Coastal Plain. All the members of this genus are considered primary burrowers, although many populations of a few species *(e.g., F. fodiens* and *F. hedgpethi)* are known to enter lentic surface waters (=secondary burrowers), especially during the spring when many small pools of water collect and these species become more active. This genus has penetrated the Interior Highlands most noticeably along the comparatively lower lying Arkansas Valley province westward from the Gulf Coastal Plain. More members of this group display the highly specialized adaptations to a burrowing existence than any other group in Arkansas.

Of the four members of the genus *Faxonella, F. blairi* and *F. clypeata* occur in Arkansas. This group, like the preceding one, probably evolved in the West Gulf Coastal Plain. These small crayfishes typically inhabit lentic waters such as roadside ditches, ponds, and backwaters of streams and are dominant inhabitants of very small streams (less than two-thirds of a meter wide). Because these species are tertiary burrowers they are able successfully to occupy seasonal waters that begin to dry in late spring. During the winter and early spring when many, often isolated, depressions fill with water, the temporary pools appear spontaneously to produce crayfishes, including members of this genus. The saturated soils and pools of water induce these tertiary burrowers back to the verdant surface.

The genus that dominates the Interior Highlands and Arkansas fauna is *Orconectes.* Nineteen species and subspecies of the 73 recognized taxa in the genus occur in Arkansas. The group probably arose on the Interior Low Plateaus province in the Tennessee-Kentucky area and spread westward around the Mississippi Embayment and found congenial habitats and niches in the Interior Highlands. In the Highlands the group has undergone a secondary radiation with many species occupying the types of habitats that members of the genus *Cambarus* had found available while spreading into the Interior Low Plateaus province from the Cumberland Plateau. The genus occurs in practically all parts of Arkansas from lowland waters *(e.g., O. palmeri* and *O. lancifer)* to the high gradient waters of the uplands occurring in both pool and riffle areas. The most impressive member of the genus, *O. longidigitus,* occurs in the White River system of Arkansas and Missouri. It is a strikingly green- to brown-colored animal, with blue to bluish-green periopods and red markings, and black on the chelae (especially the fingers) which are studded with white tubercles. The largest known specimen measured 57.2 mm, postorbital carapace length (acumen broken) (after Bouchard, 1973). The elongate chelae (up to 107.8 mm long), from which the animal derives its name, contribute to its impressive appearance.

The largest and most widespread genus of crayfishes in North America is *Procambarus* with 15 species found in Arkansas. The group occurs primarily in the Coastal Plain in lotic waters of surface streams, including backwaters, and lentic areas such as ditches, ponds, and swamps. The genus contains burrowing members as well as troglobitic ones, although no cave species occur in Arkansas. The state shares with Oklahoma the only member of the genus endemic to surface streams above the Fall Line zone (Bouchard, 1978c). This crayfish, *P. tenuis,* inhabits small, high-gradient streams of the Ouachita province. Its laterally-compressed body is similar in shape to that of *C. causeyi* (which burrows among rocks) and *O. compressus* (which burrows in gravel in the Highland Rim).

The genus also has significantly penetrated the Interior Highlands along a portion of the relatively low lying Arkansas Valley section. *Procambarus a. acutus* has gained access to the Highlands of Arkansas from the Coastal Plain to the east, reaching as far as Oklahoma, and the subgenus *Girardiella* has reached the province from the west. This dispersal corridor (Arkansas Valley) has been utilized additionally by such typically Coastal Plain species as *O. palmeri, C. diogenes,* and *F. hedgpethi* from the east.

Members of the subgenus *Pennides* display many striking color patterns of browns, blacks, and whites and are the most handsome *Procambarus* species found in Arkansas.

A comparison of our list (Table 1) of Arkansas crayfishes with that in Williams' excellent study (1954) of the Interior Highlands reveals several differences, due in part to our inclusion of many Coastal Plain species that were not within the scope of his study, as well as the descriptions of new species discovered since that time. Our omission of four species from Williams' list (1954) is due to a great deal of uncertainty concerning their occurrence in the state. A fifth species added by Reimer (1969) has been omitted because of some question concerning its taxonomic validity. *Orconectes difficilis* had been recorded from Washington County (Prairie Grove); however, not only was Williams' (1954) attempt to collect additional material of *O. difficilis* from Prairie Grove unsuccessful, but he did not find the species anywhere else in Arkansas during his survey. Recent collections by us in the Prairie Grove area also failed to produce any *O. difficilis.* We agree with Williams' questioning the inclusion of *O. difficilis* as part of the state's fauna based upon the Prairie Grove record and have omitted this species until such time as the range of the species can be found to extend into the state.

Localities for *O. luteus* formerly had been recorded from Carroll (White River, Eureka Springs) and Lawrence (Black River, Black Rock) counties, but Williams (1954) doubted the validity of the White River locality since he was not able to find *O. luteus* in that area. An established population of this species at the Black Rock locality also seems to us to be questionable, since *O. luteus* is an upland species, and Black Rock lies at the edge of the Coastal Plain. This location also is considerably downstream from any known popu-

lation of the species in the Missouri portion of this drainage making it unlikely that even waifs would occur here. We, therefore, doubt the presence of this species in the state based upon these records and have omitted it from our list.

The third species in question is *O. nais*. The populations identified as *O. nais* in Williams' study (1954) are mostly if not completely referable to *O. virilis*. A possible explanation for his confusing the two species may have originated with an earlier study of the crayfishes of Kansas by Williams and Leonard (1952). The type-locality of *O. nais* is Labette County, Kansas, where *O. virilis* is common in surface streams. A comparison by them of *O. nais* types at the Kansas University Museum of Natural History (p. 993) with specimens of *O. virilis* revealed differences in the curvature of the elements of the gonopods. Collections from Bourbon and Elk counties contained specimens with atypical gonopods that seemed to indicate to them that these and the type-material were just part of a range of variation exhibited by a single species *(loc. cit.)*. The Kansas populations of *O. virilis* were therefore referred to as *nais* and the name *virilis* applied to populations of this species "...in the northern and eastern Mississippi Valley drainage...." (Williams and Leonard, 1952). It was unfortunate that Williams and Leonard had not collected live, adult, reproductive male specimens of *O. nais* with their distinctive color pattern common to members of the Palmeri Group. The different color patterns of *O. nais* and *O. virilis* certainly would have alerted them that two morphologically very similar but separate species were present. Whether *O. nais* is still part of the Kansas fauna is not known, but *nais* has been recently collected in Texas and Oklahoma by one of us (RWB). *Orconectes nais* is not included as part of the Arkansas fauna until a confirmed population can be found in the state.

Orconectes causeyi, the fourth species lacking from our list, has been recorded from Arkansas by Reimer (1969b). He considered *O. causeyi* to be distinct from its closest ally, *O. virilis*, although he noted that it may only be a subspecies of *O. virilis*. Hobbs (1972b), however, regarded *O. causeyi* as a synonym of *O. virilis*. He later (1974) included *O. causeyi* in his Checklist, again questioning its taxonomic validity but retaining the name until a thorough study of it and *O. virilis* is undertaken. We have here followed Hobbs (1972b) in regarding *O. causeyi* as a synonym of *O. virilis*.

One additional species formerly recorded from Arkansas is *P. gracilis*. Reimer (1969a) completed an unpublished study of the Gracilis Group of the subgenus *Girardiella* in which he determined that material assigned to *P. gracilis* from Arkansas by Williams (1954) actually constituted a separate, undescribed species. This species was recently described by Fitzpatrick (1978) as *P. liberorum*, and according to Reimer *(op. cit.)* has a fairly broad range in northwestern Arkansas. We therefore have applied the available name *liberorum* to most of those populations of the Gracilis Group in northwestern Arkansas as outlined by Reimer.

Table 1. The Decapod Crustaceans of Arkansas

Family Palaemonidae
- Genus *Macrobranchium* Bate, 1868
  - *Macrobranchium ohione* (Smith, 1874)
- Genus *Palaemonetes* Heller, 1869
  - *Palaemonetes kadiakensis* Rathbun, 1902

Family Cambaridae
Subfamily Cambarellinae Laguarda, 1961
- Genus *Cambarellus* Ortmann, 1905
  - *Cambarellus puer* Hobbs, 1945
  - *Cambarellus shufeldtii* (Faxon, 1884)

Subfamily Cambarinae Hobbs, 1942
- Genus *Bouchardina* Hobbs, 1977
  - *Bouchardina robisoni* Hobbs, 1977
- Genus *Cambarus* Erichson, 1846
- Subgenus *Erebicambarus* Hobbs, 1969
  - *Cambarus (Erebicambarus) hubbsi* Creaser, 1931
- Subgenus *Jugicambarus* Hobbs, 1969
  - *Cambarus (Jugicambarus) causeyi* Reimer, 1966
  - *Cambarus (Jugicambarus) zophonastes* Hobbs and Bedinger, 1964
- Subgenus *Lacunicambarus* Hobbs, 1969
  - *Cambarus (Lacunicambarus) diogenes diogenes* Girard, 1852
  - *Cambarus (Lacunicambarus) diogenes ludovicianus* Faxon, 1885
- Genus *Fallicambarus* Hobbs, 1969
- Subgenus *Creaserinus* Hobbs, 1973
  - *Fallicambarus (Creaserinus) caesius* Hobbs, 1975
  - *Fallicambarus (Creaserinus) fodiens* (Cottle, 1863)
  - *Fallicambarus (Creaserinus) hedgpethi* (Hobbs, 1948)
- Subgenus *Fallicambarus* Hobbs, 1973
  - *Fallicambarus (Fallicambarus) dissitus* (Penn, 1955)
  - *Fallicambarus (Fallicambarus) jeanae* Hobbs, 1973
  - *Fallicambarus (Fallicambarus) spectrum* Hobbs, 1973
  - *Fallicambarus (Fallicambarus) strawni* (Reimer, 1966)
- Genus *Faxonella* Creaser, 1933
  - *Faxonella blairi* Hayes and Reimer, 1977
  - *Faxonella clypeata* (Hay, 1899)
- Genus *Orconectes* Cope, 1872
  - *Orconectes acares* Fitzpatrick, 1965
  - *Orconectes eupunctus* Williams, 1952
  - *Orconectes lancifer* (Hagen, 1870)
  - *Orconectes leptogonopodus* Hobbs, 1948
  - *Orconectes longidigitus* (Faxon, 1898)
  - *Orconectes macrus* Williams, 1952
  - *Orconectes marchandi* Hobbs, 1948
  - *Orconectes meeki brevis* Williams, 1952
  - *Orconectes meeki meeki* (Faxon, 1898)
  - *Orconectes menae* (Creaser, 1933)
  - *Orconectes nana* Williams, 1952
  - *Orconectes neglectus chaenodactylus* Williams, 1952
  - *Orconectes neglectus neglectus* (Faxon, 1885)
  - *Orconectes ozarkae* Williams, 1952
  - *Orconectes palmeri longimanus* (Faxon, 1898)
  - *Orconectes palmeri palmeri* (Faxon, 1884)
  - *Orconectes punctimanus* (Creaser, 1933)
  - *Orconectes virilis* (Hagen, 1870)
  - *Orconectes williamsi* Fitzpatrick, 1966
- Genus *Procambarus* Ortmann, 1905
- Subgenus *Girardiella* Lyle, 1938
  - *Procambarus (Girardiella) curdi* Reimer, 1975
  - *Procambarus (Girardiella) liberorum* Fitzpatrick, 1978
  - *Procambarus (Girardiella) reimeri* Hobbs, 1979
  - *Procambarus (Girardiella) simulans simulans* (Faxon, 1884)
  - *Procambarus (Girardiella) tulanei* Penn, 1953
- Subgenus *Ortmannicus* Fowler, 1912
  - *Procambarus (Ortmannicus) acutus acutus* (Girard, 1852)
  - *Procambarus (Ortmannicus) geminus* Hobbs, 1975
  - *Procambarus (Ortmannicus) viaeviridis* (Faxon, 1914)
- Subgenus *Pennides* Hobbs, 1972
  - *Procambarus (Pennides) dupratzi* Penn, 1953
  - *Procambarus (Pennides) elegans* Hobbs, 1969
  - *Procambarus (Pennides) natchitochae* Penn, 1953
  - *Procambarus (Pennides) ouachitae* Penn, 1956
  - *Procambarus (Pennides) vioscai* Penn, 1946
- Subgenus *Scapulicambarus* Hobbs, 1972
  - *Procambarus (Scapulicambarus) clarkii* (Girard, 1852)
- Subgenus *Tenuicambarus* Hobbs, 1972
  - *Procambarus (Tenuicambarus) tenuis* Hobbs, 1950

CONSERVATION STATUS OF ARKANSAS DECAPOD CRUSTACEANS

Of the many species of decapod crustaceans in Arkansas only one at this time is so rare that its conservation status is of concern. *Cambarus zophonastes*, a troglobitic crayfish, is known from a single locality in Stone County, that drains, in part, the town of Mountain View, an area experiencing continued growth. Troglobitic decapods are limited to a rather stable environment and display a lower productivity, late sexual maturity, and population structure that is in equilibrium with and adjusted to the lower energetics of the subterranean environment that relies upon allochthonous materials to fuel the food chain. Therefore, their vulnerability due to limited reproductive capabilities, smaller population sizes, sensitivity to modifications of the habitat or its cyclical events, and groundwater pollution is reason to initiate measures to protect the subterranean aquatic ecosystem of the area. Effort should also be undertaken to locate additional populations of *C. zophonastes* in order to determine whether or not its rarity is simply a reflection of limited field work in the area. A study of its biology would provide information that might aid in preserving this unique part of the Arkansas fauna.

Much work remains to be done with the Arkansas crayfishes including descriptions of several new species. The distributions of many of the Coastal Plain species have not yet been thoroughly defined, due in part to a lesser amount of sampling in the area. Range extensions for *P. elegans* and *F. dissitus* into Arkansas were discovered during our scattered field surveys, and in fact, most of the descriptions of new Arkansas species within the last decade have involved mostly Coastal Plain species. In addition to a primary understanding of many of the distributions, studies of the intraspecific variation among the state's fauna, and investigations of decapod biologies are needed.

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FOOD OF BLUEGILL AND LONGEAR SUNFISH IN DEGRAY RESERVOIR, ARKANSAS, 1976

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ABSTRACT

Stomach contents were examined from 544 bluegill *(Lepomis macrochirus)* and 709 longear sunfish *(L. megalotis)* collected from nearshore areas of DeGray Reservoir April - November 1976. Major foods of bluegill (percentage of total weight of food in parentheses) were insects (33), bryozoa (7.3), planktonic crustaceans (6.5), and plant materials (15.4). The major food items contributing to the diet of longear sunfish were insects (52.6%), crayfish (12.5%), fish (7.4%), and plant material (6.7%). Although bluegill and longear sunfish are closely related species, their diets were not as similar as expected: bluegill consumed zooplankton, adult dipterans, and adult ephemeropterans associated with limnetic areas; while longear sunfish consumed terrestrial insects, immature stages of aquatic insects, and macro-invertebrates associated with littoral areas.

INTRODUCTION

The U.S. Fish and Wildlife Service and the U.S. Corps of Engineers, in cooperation with state and private universities, are investigating the effects of multi-outlet water release on DeGray Reservoir and its tailwater. Study of the food of fishes is vital to the scientific understanding of reservoirs, and a knowledge of food habits and feeding relationships of closely related sympatric species is a prerequisite to understanding complex ecological associations.

Samples collected after the application of rotenone to coves ("cove-rotenone" samples) in August during the five-year period 1974-78 showed that the combined biomass of bluegill *(Lepomis macrochirus)* and longear sunfish *(L. megalotis)* accounted for 18 to 37% of the total fish biomass present. In 1976, longear sunfish was the dominant sunfish and the second most abundant fish in the reservoir; bluegill ranked second among sunfishes and third in number among all species (Multi-Outlet Reservoir Studies, unpublished data). To evaluate the impact of the bluegill and the longear sunfish on the ecosystem, feeding trends, selective feeding, and competition for food items between the two species and among different sizes within each species were examined.

Applegate et al. (1967) has cited many studies of bluegill food habits, but reported a lack of investigations for longear sunfish. Mullan and Applegate (1967; 1970), studying the food of longear sunfish and several other centrarchids in Bull Shoals and Beaver Reservoirs, contributed what is apparently the only published record of the food of longear sunfish.

METHODS AND MATERIALS

Study Site: DeGray Reservoir, created when the Caddo River was dammed in 1969, has an area of 5,427 ha and maximum and mean depths of 57 and 15 m at normal pool elevation, which is 124.4 m above mean sea level. The multi-outlet intake is constructed so that water can be selectively withdrawn from one of three 6.4-m^2 openings, the midpoints of which are located at elevations of 120.4, 115.8, and 108.2 m (Middleton, 1967). Water was discharged exclusively from the epilimnial outlet (120.4 m) throughout our investigation (Moen and Dewey, 1978).

Food Habits: To assess many of the biological and physical properties, the reservoir was divided into three compartments corresponding to upper, middle, and lower portions. Each compartment was further divided into five equal lengths of shoreline, and one compartment and one length of shoreline were randomly selected without replacement so that from April through November, bluegill and longear sunfish were sampled in each of the 15 areas. We attempted to collect 50 fish of each species (ten fish in each of five length classes of 0-50, 51-75, 76-100, 101-125, and 125 mm in total length) by electrofishing near shore after sundown for two hours. Upon capture, fish were placed in an ice slurry to prevent regurgitation, then preserved in 10% formalin, and grouped by species, date, reservoir compartment, and length class.

Stomach contents were pooled by species and size class, and food items were identified to the lowest taxon distinguishable by us. Food items from fish of each length class (pooled) were drained, blotted, and weighed to the nearest 0.1 mg.

RESULTS AND DISCUSSION

Bluegill Food: Of the 544 bluegill stomachs examined, 91% contained food. Major animal foods were insects, bryozoans, and planktonic crustaceans, which made up 33, 7.3 and 6.5% of the total diet, respectively. Plant material, mostly filamentous algae and organic debris, contributed 15.4% of their total diet (Table 1). Of the animal material (84.5% of the total), nearly one-third could not be identified. Generally, the amount of identifiable animal material increased as seasons progressed from spring to fall and as fish size increased. Food items for 497 bluegills are tabulated by season and fish size in Tables 2, 3, and 4. Feeding patterns generally were related to season availability of food items and fish size.

Aquatic insects made up most of the diet of bluegill in each size class and season, except in fish larger than 75 mm, which fed almost exclusively on plant material (mostly filamentous algae) during late fall. Consumption of immature aquatic insects decreased as bluegill size increased, ingesting more emerging aquatic insects. Terrestrial insects contributed less than 25% of all insects consumed; mayflies and aquatic dipterans accounted for the remainder. The quantity of terrestrial insects eaten was correlated with fish size. Terrestrial insects included beetles (e.g., June bugs, Phyllophaga), leaf hoppers, grasshoppers, and spiders. Although bryozoa made up only 7.3% of the total diet, large (greater than 125 mm) bluegill ingested greater quantities of these animals during late fall. During October and November, bryozoa made up 34.9% of the diet of 23 large bluegill. Planktonic crustaceans were important only in the diet of bluegill less than 50 mm. Weight of microcrustaceans consumed decreased seasonally (spring to fall).

Fish eggs were found in bluegill of all length groups collected during April and June and comprised up to 24.8% of the food of bluegill 51-75 mm (Table 2). By season, fish eggs made up less than 5% of the diet of the remaining four size groups. Fish remains were noted in several of the pooled samples, but made up less than 1% of the diet by season and length groups except one (fish composed 18.7% of the total for bluegill over 125 mm during July-September).

Bluegill over 50 mm consumed more plant material than did smaller specimens, especially during the fall. The percentage of plant material, mostly filamentous algae, consumed during October and November ranged from 1.6% for specimens less than 50 mm to 66.7% in fish 76-100 mm.

Food of Longear Sunfish: Of 709 longear sunfish stomachs examined, 644 (91%) contained food. Animal material made up 93.3% of the total weight, but approximately one-fourth of this material could not be identified. Insects, crayfish, and fish made up 52.6, 12.5 and 7.4% of the total diet, respectively; plant material made up 6.7% (Table 1). Food for longear by season and length groups is presented in Tables 2, 3, and 4.

Aquatic insects were only slightly more important than terrestrial insects in the diet of all longear sunfish. There was little correlation between size of longear sunfish and the consumption of immature or adult aquatic insects. By contrast, the consumption of terrestrial insects was positively correlated (r = 0.81) with fish length. Crayfish were eaten in significant amounts only by fish over 76 mm and made up a maximum of 15.1% of the diet of fish 101-125 mm (Table 1). Crayfish were taken primarily in the late summer and fall, accounting for 22.9% of the October and November food of fish over 125 mm (Table 4). Fish prey in the diet increased with predator size and reached a maximum of 9.3% in the diet of fish over 125 mm. Fish eggs were among the more important seasonal foods, appearing mostly in April through June and in the stomachs of fish less than 100 mm. Fish eggs composed 38% of the diet of longear sunfish less than 50 mm during April through June.

There was no relationship between the amount of plant material ingested and fish size. Most of the plant material was organic debris (3.3%); filamentous algae and fragments of macrophytes contributing equally to the remaining 3.4%. Of the plant material in longear stomachs, filamentous algae was the most important. The largest amounts were found in larger fish during October and November.

Comparison of Food for the Two Species: Although bluegill and longear sunfish are closely related species, their diets were not as similar as expected. Insects were the most important and the most consistently major food item for both species. However, there were differences between species as to source and types of insects consumed. Terrestrial insects and aquatic insects each made up nearly 50% of the insects in the diet of longear sunfish (22.5 and 30.1%, respectively), whereas terrestrial insects made up only 25% of the insect diet of bluegill. Immature aquatic insects were more prominent in the diet of longear sunfish than in that of bluegill. They were equally represented in all sizes of longear sunfish, whereas they were more strongly represented in small rather than large bluegill.

The consumption of terrestrial insects was greatest in spring and early summer (April-June) for both fishes. Terrestrial insects made up a greater proportion of the diet as the size of the fish increased. Adult aquatic insects were the major food items taken by bluegill, comprising nearly 50% of their total insect intake — about the same ratio that terrestrial insects were to the insect consumption by longear (Table 1).

Crayfish were missing in the diet of bluegill, but were taken by all sizes except the smallest longear. Crayfish made up about 20% of the food of longear sunfish over 100 mm during late summer and fall (July-November). Applegate et al. (1967) reported that crayfish were eaten by all species of sunfishes collected from Bull Shoals Reservoir, but were important only in the diet of large green sunfish *(L. cyanellus)*.

Differences in the food intake of these two species appear to support the hypothesis of a spatial segregation, at least during a portion of the diel cycle. Bauman and Kitchell (1974) reported that the bluegill of Lake Wingra, Wisconsin, migrated onshore after sunset and offshore after sunrise, and that they consumed mostly zooplankton in limnetic areas and macrofoods in the littoral zone. Werner et al. (1977) observed that during midday, longear sunfish were more abundant than bluegill in the littoral areas and that bluegill moved toward shore in the evening. They also noted that longear sunfish methodically search the bottom for food organisms. In the present study, bluegill consumed more zooplankton (mostly cladocerans) than did longear sunfish for each comparable size class and for each season (Tables 2, 3, and 4). Bluegill also consumed more adult dipterans and ephemeropterans associated with the surface of limnetic waters than with the limited areas of the littoral zone. Longear sunfish consumed more terrestrial insects, immature aquatic insects, and macroinvertebrates associated with littoral areas than did bluegill. It appears that longear sunfish are more ecologically oriented to the littoral zone than bluegill, except during the onshore migrations by the latter species. If this hypothesis is correct, differences in food consumption should be greater if fish are sampled from these respective areas during midday.

Table 1. Percent by weight of the major foods eaten by five length classes of bluegills and longear sunfish from DeGray Lake, 15 April - 1 November, 1976 (t = trace, or <0.05%).

Food	LENGTH GROUP, SPECIES, NUMBER OF STOMACHS EXAMINED, AND (IN PARENTHESES) PERCENT CONTAINING FOOD											
	≤50 mm		51-75 mm		76-100 mm		101-125 mm		>125 mm		All Lengths Combined	
	Bluegill	Longear	Bluegill	Longear	Bluegill	Longear	Bluegill	Longear	Bluegill	Longear	Bluegill	Longear
	98	118	144	138	130	136	74	144	98	121	544	709
	(92.9)	(96.6)	(92.4)	(96.4)	(98.5)	(86.1)	(91.9)	(85.4)	(88.8)	(87.2)	(91.4)	(90.8)
FOOD CATEGORY												
Animal	98.1	94.0	88.5	96.3	82.4	91.0	87.2	94.2	83.9	92.7	84.5	93.3
Unidentified	46.2	42.5	28.3	35.3	15.9	24.0	34.2	19.9	29.5	12.6	31.3	17.4
Identified	30.2	36.1	60.2	59.0	66.6	67.0	53.0	74.3	53.8	80.1	53.2	75.9
Insects	29.8	35.8	33.7	51.9	58.9	51.0	40.4	49.9	29.2	36.4	33.0	52.6
Aquatic	25.8	24.8	33.1	25.3	32.0	44.4	36.2	34.8	18.7	23.8	23.0	30.1
Adult	1.9	1	4.8	1	19.8	12.4	16.4	2.9	14.3	3.6	15.0	4.0
Immature	27.9	24.8	28.9	27.3	12.2	32.0	19.8	31.9	4.4	22.2	10.0	26.1
Terrestrial	-	1.0	2.0	4.4	8.1	6.8	4.3	15.1	10.4	30.6	8.0	22.5
Crayfish	-	-	-	3.7	-	5.2	-	15.1	-	11.8	-	12.5
Fish	-	-	4	0.3	0.3	1.8	0.5	0.6	4.6	9.3	4.1	7.4
Fish eggs	1	22.8	15.2	10.1	2.0	4.8	1.8	0.2	0.1	0.3	1.8	1.9
Bryozoa	-	-	0.4	-	2.9	0.4	4.2	t	10.2	t	7.3	t
Planktonic crustaceans	20.4	8.9	5.7	4.9	3.2	1.0	4.4	1.2	1.4	0.2	4.1	1.4
Other	1	1.0	1.2	1.0	1	0.8	1.1	1.0	0.3	0.2	0.7	0.4
Plant	1.6	1.0	11.4	3.7	17.7	9.0	12.8	5.8	16.0	7.3	15.4	6.7
Algae	1.0	t	8.1	0.3	13.7	2.6	7.2	2.1	9.4	1.1	9.2	1.8
Green fragments	-	-	0.8	t	2.0	0.8	2.3	1.8	2.3	1.8	2.1	1.8
Debris	-	1.0	4.1	3.4	2.0	5.8	3.3	1.5	4.3	3.9	4.1	3.1

Table 2. Percent by weight of the major foods eaten by five length classes of bluegills and longear sunfish from DeGray Lake, 15 April - 15 June, 1976 (t = trace, or <0.05%).

Food	LENGTH GROUP, SPECIES, NUMBER OF STOMACHS EXAMINED, AND (IN PARENTHESES) PERCENT CONTAINING FOOD									
	0-50 mm		51-75 mm		76-100 mm		101-125 mm		>125 mm	
	Bluegill	Longear	Bluegill	Longear	Bluegill	Longear	Bluegill	Longear	Bluegill	Longear
	42	34	55	70	53	66	29	33	34	34
	(45.2)	(100)	(87.3)	(42.4)	(86.8)	(86.4)	(86.2)	(81.8)	(84.8)	(88.2)
FOOD CATEGORY										
Animal	100	99.6	96.8	86.4	85.7	88.7	95.3	92.0	95.4	98.8
Unidentified	39.4	29.3	22.7	35.0	45.4	23.8	55.1	18.3	41.7	12.1
Identified	61.4	64.4	74.1	51.4	53.3	67.1	40.8	78.7	54.4	86.5
Insects	32.5	33.2	40.5	24.2	44.5	55.4	23.5	55.8	37.0	66.4
Aquatic	32.3	23.7	37.8	17.4	31.3	48.1	17.7	46.9	14.1	24.9
Adult	3.4	0.4	3.2	-	15.4	16.9	7.8	-	6.3	3.5
Immature	28.9	23.3	32.4	17.4	11.9	31.8	10.7	46.9	6.8	21.4
Terrestrial	-	9.7	2.9	6.8	6.2	6.2	5.8	16.9	22.9	39.5
Crayfish	-	-	0.3	0.2	-	-	-	1.0	-	0.1
Fish	-	-	-	-	0.7	0.6	0.3	15.5	0.1	10.7
Fish eggs	1.2	30.1	24.9	28.7	4.1	8.5	4.2	0.3	0.3	0.4
Bryozoa	-	-	-	-	1.3	0.1	0.3	-	t	t
Planktonic crustaceans	29.3	7.4	7.4	5.9	5.3	1.4	10.6	-	11.8	0.6
Other	1.2	1.2	0.9	0.6	0.2	0.2	1.1	0.1	0.2	0.3
Plant	t	0.4	1.2	3.6	4.2	6.3	4.1	1.0	4.6	1.2
Algae	-	-	1.0	0.2	1.1	0.1	2.7	0.3	0.8	0.1
Green fragments	-	-	-	-	0.2	t	-	0.1	-	0.4
Debris	t	0.4	0.2	3.1	2.7	6.0	1.4	2.6	1.8	0.7

Table 3. Percent by weight of the major foods eaten by five length classes of bluegills and longear sunfish from DeGray Lake, July - September, 1976 (t = trace, or <0.05%).

Food	0-30 mm		31-75 mm		76-120 mm		121-172 mm		2173 mm	
	Bluegill	Longear	Bluegill	Longear	Bluegill	Longear	Bluegill	Longear	Bluegill	Longear
	42	49	80	80	48	80	80	80	78	66
	(95.2)	(98.0)	(93.0)	(98.7)	(93.8)	(98.7)	(98.7)	(95.0)	(86.1)	(95.1)
FOOD CATEGORY										
Animal	100.0	96.7	76.4	95.1	80.3	95.3	86.0	95.6	77.1	95.7
Unidentified	38.8	34.1	45.2	33.7	33.9	25.1	15.7	18.4	25.2	11.7
Identified	61.4	62.6	31.2	61.4	46.8	70.2	70.3	77.0	51.9	74.0
Insects	33.5	34.4	27.9	48.4	46.3	58.0	61.0	52.3	24.1	46.4
Aquatic	33.5	34.4	27.0	47.9	46.4	45.3	36.0	33.6	23.6	28.4
Adult	2.4	-	4.0	0.4	25.5	12.3	28.1	5.4	20.2	5.0
Immature	30.1	34.4	18.0	47.2	15.1	33.0	28.7	28.2	3.2	21.4
Terrestrial	-	-	-	0.8	5.7	4.7	4.2	18.7	0.7	23.0
Crayfish	-	-	-	11.0	-	5.4	-	19.9	-	20.9
Fish	-	-	-	0.4	-	12.0	0.8	3.0	18.7	5.2
Fish eggs	1.2	-	-	-	-	-	-	0.2	-	0.1
Bryozoa	-	-	0.8	-	-	-	8.7	-	8.5	-
Planktonic crustaceans	24.5	6.8	3.0	0.4	0.5	-	0.2	-	t	-
Other	1.2	1.8	0.8	0.4	-	2.6	1.8	1.8	0.6	0.7
Plant	-	3.3	23.6	4.9	19.7	4.7	14.0	4.4	22.9	4.3
Algae	-	-	10.8	-	13.9	-	7.2	-	15.0	1.8
Green fragments	-	-	1.8	0.4	4.1	2.2	4.0	3.5	3.8	0.7
Debris	-	3.3	11.0	4.5	1.7	2.5	2.8	1.1	2.1	7.0

Table 4. Percent by weight of the major foods eaten by five length classes of bluegills and longear sunfish from DeGray Lake, October - November, 1976 (t = trace, or <0.05%).

Food	0-30 mm		31-75 mm		76-120 mm		121-172 mm		2173 mm	
	Bluegill	Longear	Bluegill	Longear	Bluegill	Longear	Bluegill	Longear	Bluegill	Longear
	20	30	39	39	29	30	15	19	23	29
	(100)	(96.9)	(96.6)	(100)	(93.1)	(86.7)	(93.3)	(84.7)	(100)	(82.1)
FOOD CATEGORY										
Animal	190.0	100.0	74.9	96.1	53.4	86.5	56.6	85.1	68.0	73.4
Unidentified	89.3	96.0	17.9	73.1	16.7	25.0	32.1	33.9	15.6	18.4
Identified	10.8	4.0	56.9	23.0	36.7	61.5	23.9	45.2	48.6	15.0
Insects	7.2	-	55.8	15.3	15.5	58.2	13.3	26.0	13.7	25.0
Aquatic	7.2	-	53.8	13.6	13.5	26.9	12.2	16.9	5.6	19.4
Adult	3.6	-	47.2	-	4.4	-	0.8	16.7	7.3	-
Immature	3.6	-	6.6	13.6	9.1	26.9	11.4	0.2	2.3	19.4
Terrestrial	-	-	-	1.9	-	4.3	-	7.1	4.3	4.8
Crayfish	-	-	-	-	-	20.0	-	21.7	-	22.9
Fish	-	-	0.9	-	-	0.8	-	0.2	-	1.1
Fish eggs	-	-	-	-	-	-	-	-	-	-
Bryozoa	-	-	-	-	2.0	2.1	11.4	-	16.9	-
Planktonic crustaceans	2.6	4.8	1.9	4.8	-	-	0.3	0.4	-	-
Other	-	-	-	2.5	-	0.8	-	2.9	-	-
Plant	t	-	25.5	3.7	84.6	13.5	43.8	14.9	32.0	26.6
Algae	-	-	24.9	3.7	65.8	12.3	25.4	14.2	18.2	11.4
Green fragments	-	-	-	-	-	-	4.3	-	1.2	1.7
Debris	t	-	0.6	1.0	0.8	1.2	13.7	0.70	12.6	13.5

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FOOD OF LARGEMOUTH BASS *(MICROPTERUS SALMOIDES)* IN DEGRAY RESERVOIR, ARKANSAS, 1976

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ABSTRACT

Stomach contents were examined from 748 largemouth bass, *Micropterus salmoides* (<125 mm total length), collected from DeGray Reservoir during April-November 1976. Fish constituted 59% by weight of the total diet and occurred in 81% of the stomachs; crayfish made up nearly 38% of the weight and occurred in 24% of the stomachs. Sunfish, the principal fish food (about 28% by weight), were observed in 36% of the stomachs. Shad were the second most important prey (23% by weight and 29% frequency in occurrence). Crayfish constituted about 42% of the total weight of the food of bass 200 mm long or longer, but only 12% in bass less than 200 mm. Crayfish consumption was greatest during the fall.

INTRODUCTION

The U. S. Fish and Wildlife Service and the Waterways Experiment Station, U. S. Army Corps of Engineers, in cooperation with state and private universities, are investigating the effects of multi-outlet water release on DeGray Reservoir and on its tailwater. Multipurpose DeGray Reservoir, located on the Caddo River in Arkansas, has a surface area of 5,427 ha at normal pool elevation (124.4 m above mean sea level). A description of DeGray Reservoir was published by Moen and Dewey (1978). The multi-outlet design at DeGray dam allows for discharge from the epilimnion, the hypolimnion, or from an intermediate depth.

An improved scientific understanding is needed to enable more accurate prediction of the effects of water release depth on the biological production in the reservoir. A major deficiency in the understanding of reservoir fish population dynamics stems from the lack of data on predator-prey relations (Jenkins and Morais, 1976). A knowledge of the food habits of fish is vital to the understanding of reservoirs. In DeGray Reservoir it was assumed that threadfin shad *(Dorosoma Petenense)* and young gizzard shad *(D. cepedianum)* would be the major prey, and largemouth bass *(Micropterus salmoides)* the major predator. Low production of shad, coupled with high crops of bluegills *(Lepomis macrochirus)* and longear sunfish *(L. megalotis)* estimated from cove rotenone samples in 1974 and 1975, stimulated interest in the role of sunfish and other food sources. The purpose of this study was to determine the contribution of major food items to the diet of largemouth bass.

METHODS AND MATERIALS

Study Site: DeGray Reservoir, created when the Caddo River was dammed in 1969, has an area of 5,427 ha and maximum and mean depths of 57 and 15 m at normal pool elevation, which is 124.4 m above mean sea level. The multi-outlet intake is constructed so that water can be selectively withdrawn from one of three 6.4-m^2 openings, the midpoints of which are located at elevations of 120.4, 115.8, and 108.2 m (Middleton, 1967). Water was discharged exclusively from the epilimnial outlet (120.4 m) throughout our investigation (Moen and Dewey, 1978).

Food Habits: Largemouth bass were sampled on the same schedule and at the same time described for longear and bluegill sunfish in the previous paper. Largemouth bass were placed on ice immediately after capture and returned to the laboratory, where they were weighed, measured, and scale sampled. Stomachs were excised and preserved in 10% formalin for later examination.

Stomachs were split longitudinally and the food contents of individual stomachs were examined. Food items were separated to the lowest taxon identifiable by us, and material of each taxon was drained, blotted, and weighed (to the nearest 0.01g). Fish as food items were grouped into three major categories; sunfish, shad, and miscellaneous fish. The last named category included: minnows (Cyprinidae), madtoms *(Noturus* sp.), brook silverside *(Labidesthes sicculus)*, white bass *(Morone chrysops)*, and darters (Percidae). Shad could be positively identified even in advanced stages of digestion by the presence of the gizzard (Bryant and Morais, 1970).

The examination of food in relation to size of bass was limited to two categories; less than 200 mm (here termed small bass) and 200 mm or longer ("large bass"). All small bass were yearlings when sampling began in April, but a few young-of-the-year reached 125 mm (and were thus included in the collections) by August.

RESULTS AND DISCUSSION

Of 748 largemouth bass stomachs examined, 83% contained food (Table 1). The largest proportion of stomachs containing food was in bass collected in midsummer. Fish made up 59% of the total weight of food and occurred in 81% of the stomachs. Sunfish were the most important prey fish (27.7% of total weight). Shad were the second most abundant fish both by weight and frequency of occurrence. Crayfish constituted 37.6% of the total weight and occurred in 24.4% of the stomachs.

The major food items (fish and crayfish) occurred during all collection periods in both size groups of bass (Fig. 1 and 2). Fish made up 54.5% and crayfish 42.3% of the weight of food of large bass. Crayfish were more prevalent from July through November. However, during the early sampling periods (April through June), sunfish made up the highest percentage of total biomass (47.7%), whereas shad were highest in frequency of occurrence. Fish constituted 83.7% of the weight of the food of small bass, whereas crayfish made up only 11.9%; however, from July through September crayfish were eaten in significant numbers (27% of the total diet by weight). Shad was the principal food of small bass, contributing 37% of the total weight and occurring in 26.7% of the stomachs. Sunfish ranked second, contributing 30% of the total weight. From April through June, sunfish and miscellaneous fish accounted for the bulk of food biomass (76%) eaten by small bass. From July through September, crayfish, sunfish, and shad made up about equal amounts by weight, and in October and November shad was the principal food, composing 65% by weight and occurring in 70% of the stomachs.

The weight of consumed shad progressively decreased from compartments I through III (Table 2). Midwater trawl catches of juvenile shad followed the same pattern of decreasing abundance from compartments I through III (Multi-Outlet Reservoir Studies, unpublished data). In the upper compartment, shad was the predominant food by

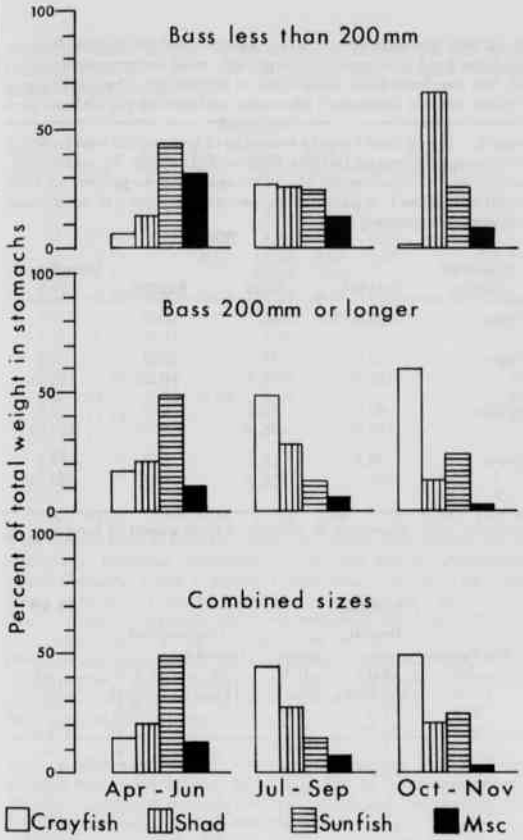

Figure 1. Seasonal distribution of major food items in the stomachs of largemouth bass from DeGray Reservoir, 15 April - 15 November, 1976, expressed as percent of total weight of food. (MSC = miscellaneous fishes; see footnote a, Table 3, for species composition.)

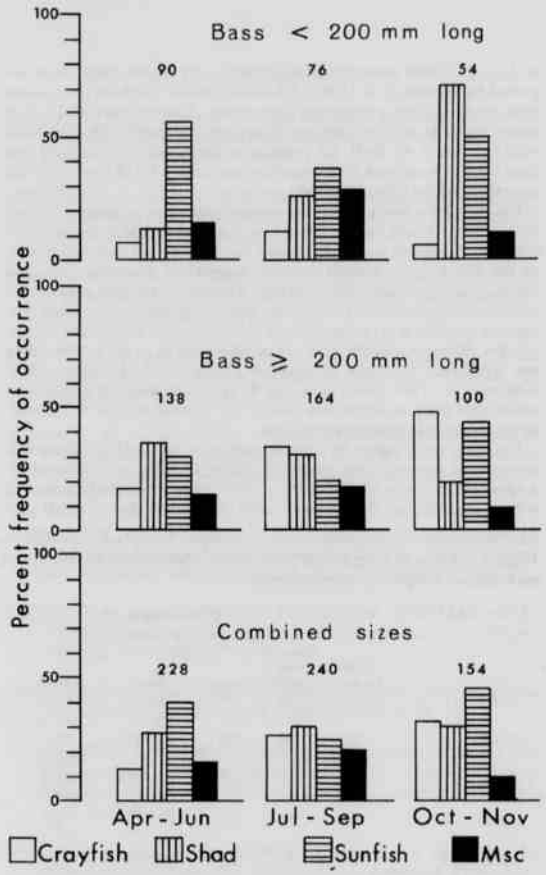

Figure 2. Seasonal distribution of major food items in the stomachs of largemouth bass from DeGray Reservoir, 15 April - 15 November, 1976, expressed as percent frequency of occurrence. Number of stomachs with food indicated by season and size (MSC = miscellaneous fishes; see footnote a, Table 3, for species composition).

weight; sunfish ranked third by weight and first in frequency of occurrence; crayfish ranked second in biomass and third in frequency of occurrence. In the middle and lower compartments, crayfish ranked first by weight and shared second ranking with sunfish in frequency of occurrence.

When stomach contents of fish collected in different seasons are examined, investigators must consider seasonal changes in water temperature and changes in digestion rates. Food may be digested five to six times faster during summer than during winter (Johnson and Charlton, 1960; Molnar and Tolg, 1962). In addition, various food items may differ in the retention of identifying characteristics during the course of digestion. For example, crayfish may be identifiable even when badly fragmented because the integument breaks down slowly. Similarly, threadfin and gizzard shad can be identified during the advanced stages of digestion by the presence of the gizzard (Bryant and Morais, 1970). Smaller prey organisms may lose their identity shortly after ingestion. Digestion rates, as influenced by temperature, could bias the relative importance assigned to different organisms.

Diel variation in feeding and time of collection strongly influence the number of empty stomachs and the amounts of food in stomachs. In the present study, feeding activity of bass apparently was intense immediately before and during collection. Although we found that 83% of all bass contained food, Aggus (1972) found this percentage to be only 47% among bass caught by anglers in Bull Shoals Reservoir. Similarly, Zweiacker and Summerfelt (1973) reported that stomachs of 45% of the bass in Lake Carl Blackwell contained food. Collections by Aggus (1972) and Zweiacker and Summerfelt (1973) were made throughout the year, and those by Zweiacker and Summerfelt were made during the morning (0600-1200 hours) and afternoon (1200-2300). After examining reports of other investigators, these authors suggested that 56% (the frequency of occurrence of empty stomachs) might be used to evaluate forage availability for largemouth bass. Such a guideline may be useful only under general conditions. However, because foraging is strongly influenced by seasonal water temperature, time of day, behavior, and prey availability, we believe it is of limited value for most fishery investigations.

Further evidence that feeding was intense during our sampling period is indicated by the ratio of stomach content weight to weight of fish. Small bass contained an average of 18 grams of food per kilogram of fish; the monthly range was 10.5 to 37 g/kg. Large bass contained 12.4 g of food per kilogram of fish; the monthly range was 8.8

to 15.4 g. These amounts were considerably higher than those reported by Heman et al. (1969), who used similar methods to examine bass feeding after a reservoir drawdown. The amount of food in stomachs of bass from DeGray Reservoir was positively correlated with fish size ($r = .914$). Six percent of the stomachs contained less than 0.1 g of food, and 38% contained more than 1 g of food; one fish contained 60.7 g (55g/kg of fish).

Crayfish have been somewhat overlooked as an important forage item of largemouth bass in reservoirs. Lorman and Magnuson (1978) stated that crayfish were not an ideal food source because about 50% of the dry weight of adult crayfish consists of inorganic salts and chitin, which are indigestible by fish. Therefore, crayfish may not be as valuable for providing energy as are fish; however, the large biomass of crayfish in largemouth bass stomachs must be considered important. Bass apparently maintain normal growth patterns when they eat significant numbers of crayfish (Taub, 1972; Lambou, 1961; Heman et al., 1969; Lewis et al., 1974). Although crayfish may be less vulnerable prey for some fish (Stein, 1977), they appear to be relatively vulnerable to largemouth bass.

Crayfish were eaten by largemouth bass in DeGray Reservoir throughout the year, but primarily during October and November. Aggus (1972) observed that more crayfish were consumed during the winter than during the summer, and concluded that crayfish sustained bass and were beneficial for gamete production. Crayfish, the dominant food in stomachs of large bass, were consumed during the fall, but also were eaten from April to September. The utilization of crayfish was not diminished when shad and sunfish populations were

Table 2. Major food items in stomachs of largemouth bass from the three compartments of DeGray Reservoir (I, upper; II, middle; III, lower), April 15-November 15, 1976, expressed as percent of total weight of food and, in parentheses, percent frequency of occurrence in stomachs containing food.

Reservoir Section	FOOD Crayfish	Shad	Sunfish	Miscellaneous Fish
Upper	32.0	34.7	27.3	
Upper	32.0 (16.7)	34.7 (29.9)	27.3 (41.2)	4.2 (13.2)
Middle	40.3 (27.7)	23.2 (38.3)	25.3 (27.7)	7.6 (18.0)
Lower	38.2 (24.7)	12.3 (12.3)	33.2 (35.2)	12.1 (24.7)

Table 1. Food of largemouth bass shown with collection dates, DeGray Reservoir, 1976, expressed as percent of total weight of food and, in parentheses, frequency of occurrence.[a]

		Total Stomachs	Stomachs with Food (%)	Total Length of Fish (mm) Average	Range	ANIMALS Fish Sunfish	Shad	Miscellaneous	Insects Crayfish	Aquatic	Unidentified Terrestrial		PLANTS
April	15	50	58	288	154-535	48.3 (41.4)	33.3 (6.9)	3.2 (13.8)	8.0 (13.8)	0.3 (20.7)	0.7 (17.2)	0.2 (13.8)	1.1 (10.3)
May	3	50	78	233	140-451	36.0 (48.7)	—	20.0 (28.2)	41.0 (30.8)	0.5 (7.7)	—	0.5 (12.8)	2.0 (12.8)
May	17	48	83	213	134-424	85.4 (67.5)	5.1 (12.5)	3.8 (5.0)	4.2 (10.0)	0.1 (5.0)	— —	1.4 (12.5)	—
June	1	50	92	197	127-411	68.3 (43.5)	18.6 (28.3)	8.5 (15.2)	1.8 (8.7)	0.1 (4.3)	t (2.2)	0.4 (13.0)	0.6 (2.2)
June	14	31	90	258	142-409	33.0 (35.7)	12.8 (21.4)	26.1 (17.9)	25.6 (10.7)	0.1 (3.6)	0.6 (7.1)	1.3 (28.6)	0.5 (10.7)
June	28	50	92	220	166-300	—	68.0 (76.1)	24.9 (19.6)	6.7 (6.5)	0.2 (6.5)	—	0.2 (2.2)	—
July	12	50	92	191	145-330	29.0 (41.3)	25.7 (21.7)	10.4 (21.7)	25.2 (13.0)	5.1 (28.3)	t (2.1)	3.5 (17.4)	1.1 (8.7)
July	26	25	100	237	166-439	12.8 (0.24)	27.2 (36.0)	12.7 (28.0)	46.5 (16.0)	0.5 (16.0)	0.2 (8.0)	—	0.1 (8.0)
Aug.	9	48	92	236	186-330	17.7 (31.8)	26.2 (36.4)	15.8 (15.9)	38.8 (18.2)	0.7 (15.9)	0.2 (4.5)	0.1 (2.2)	0.5 (11.4)
Aug.	23	50	96	248	193-352	3.7 (8.3)	32.5 (45.8)	1.5 (6.3)	51.5 (41.8)	0.2 (12.5)	—	0.8 (4.2)	0.1 (4.2)
Sept.	7	49	82	248	130-460	27.3 (32.5)	3.9 (7.5)	4.8 (27.5)	59.3 (42.5)	0.1 (5.0)	—	—	0.2 (5.0)
Sept.	20	48	77	239	132-409	12.7 (27.0)	48.5 (29.7)	11.6 (27.0)	26.1 (21.6)	—	0.4 (8.1)	0.6 (2.7)	0.1 (5.4)
Oct.	4	50	88	222	136-450	20.7 (40.9)	49.5 (45.5)	—	28.5 (20.5)	0.5 (6.8)	—	0.2 (4.5)	0.6 (9.1)
Oct.	18	49	84	246	132-422	43.6 (58.5)	22.4 (22.0)	4.3 (12.2)	29.5 (36.6)	—	—	0.2 (4.9)	t (2.4)
Nov.	1	50	74	227	148-498	14.4 (44.7)	19.0 (40.5)	—	66.4 (18.9)	—	0.2 (2.6)	t (2.7)	—
Nov.	15	50	64	297	150-521	14.2 (35.5)	1.9 (9.4)	9.5 (32.3)	74.0 (59.4)	0.2 (3.2)	—	0.2 (12.5)	—
Mean Total		748	83	234	127-535	27.7 (36.0)	23.3 (28.8)	8.0 (16.2)	37.6 (24.4)	0.3 (8.5)	0.1 (2.7)	0.5 (8.0)	0.5 (5.5)

[a]Food items not shown in the table [and not] included in the totals were amphibians 2.0 (1.6) and miscellaneous animals t (.05). The dates of collection, percent of total weight, and, in parentheses, frequency of occurrence of the items were as follows: amphibians — April 5, 4.9 (6.9); June 1, 1.7 (2.2); August 23, 9.7 (10.4); and September 7, 4.4 (2.5). Miscellaneous animals: May 3, t (5.1); and June 1, t (2.2).

Table 3. Mean weight (kg/ha) of available prey by size group, DeGray Reservoir, 1976, as determined from August rotenone samples (from Jenkins, 1976).

Length Group (mm)	SPECIES[a] Shad	Red-horse	Cat-fish	Sun-fish	Black bass	Crappie	Misc. Fish	Total
b								
25				2.43				2.43
51	11.50		0.01	4.11	0.12	0.06		15.80
76	6.53		0.01	17.96	0.81	0.05		25.36
102	2.30		t	16.09	0.47	t		18.86
127	0.24	0.01	0.02	7.74	0.37			8.38
152		0.04		7.02	0.05	0.12		7.23
178	0.12	0.21		4.96				5.29
203		0.85	0.10	4.72				5.67
229	9.44	0.61		1.74				11.79
254	25.77	0.85	0.04	0.24				26.90
279	17.18							17.18
305	13.55							13.55
330	2.30							2.30
336	2.30							2.30
25-127							4.44	4.44
Total	91.23	2.57	0.18	67.01	1.82	0.23	4.44	167.48

[a]Fish species were as follows: shad *(Dorosoma cepedianum* and *D. petenense)*, redhorse *(Moxostoma erythurum* and *M. duquesnei)*, catfish *(Ictalurus melas, I. natalis, I. punctatus, I. furcatus* and *Pylodictis olivaris)*, sunfish *(Lepomis cyanellus, L. gulosus, L. machochirus, L. megalotis,* and *L. microlophus)*, black bass *(Micropterus dolomieui, M. punctulatus,* and *M. salmoides)*, crappie *(Pomoxis annularis* and *P. nigromaculatus)*, and miscellaneous fish (Cryprinidae, *Aphredoderus sayanus, Fundulus olivaceus, Labidesthes sicculus, Morone chrysops,* and Percidae).
[b]Mid-point of inch-groups.

high, as shown by August cove rotenone samples. For small bass, crayfish dominated the prey taken from July to September, suggesting that largemouth bass selected for crayfish and that crayfish were important in predator-prey interactions.

Largemouth bass of both size categories consumed sunfish from April through June, consuming larger though fewer sunfish during this period. Sunfish were the most abundant prey during this interval. Sunfish consumption decreased from July through September but increased slightly in October and November, accompanied by a decrease in shad consumption (Fig. 1 and 2).

Young-of-the-year shad first appeared in bass stomachs on 17 May and reached a maximum by 28 June, when they constituted 68% by weight and occurred in 76% of all stomachs (Table 1). Estimates of the numbers of young-of-the-year shad, based upon samples collected in midwater trawls, were high in 1976 and reached a peak on 17 June. During August, estimates of the standing crop of shad in the one- to three-inch groups in coves (collected after the application of rotenone) were twice as high as those of similar-sized sunfish (Table 3). Thus, even though the available crops of shad were considerably higher than those of sunfish, they generally did not dominate the dietary intake. In this study, we collected no shad along the shoreline but frequently collected young sunfish.

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THE FISHES OF ROCK CREEK, SHARP COUNTY, ARKANSAS

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ABSTRACT

A survey of the fishes of Rock Creek in northcentral Arkansas was made on 9-10 November, 1978, and 15-16 March, 1979. Field collections were made using a minnow seine and backpack shocker. The creek system was inhabited by 28 species of fish representing eight families. Fish collections were typical of a small Ozark stream. The most abundant species were: *Campostoma oligolepis* Hubbs and Greene, largescale stoneroller; *Notropis telescopus* (Cope), telescope shiner; *Notropis zonatus* (Putnam), bleeding shiner; *Moxostoma duquesnei* (Lesueur), black redhorse; *Etheostoma blennioides* Rafinesque, greenside darter; *Etheostoma caeruleum* Storer, rainbow darter; *Etheostoma euzonum* (Hubbs and Black), Arkansas saddled darter; *Etheostoma spectabile* (Agassiz), orangethroat darter; and *Cottus bairdi* Girard, mottled sculpin. *Lampetra aepyptera* (Abbott), least brook lamprey, represented an extension of the previously known range of this species in the state.

INTRODUCTION

Rock Creek is a predominantly clear, spring-fed Ozark stream totally within Sharp County, Arkansas. The main spring area is referred to as Bubbling Springs and consists of one large spring with approximately one acre of numerous small bubbling springs. Six small intermittent tributaries flow into Rock Creek producing an upper stream with swift, long, narrow riffles and short, shallow pools and a lower section of long, swift, wide riffles and long wide pools (Fig. 1). The watershed consists of hardwood woodlands with few open fields. The substrate is composed of bedrock and gravel with varying sizes of swift riffles separating the pool areas. Periods of floodwater flush the system free of leaf and limb detritus each year. From the headwaters to the mouth, which empties into Spring River, the distance is 14 kilometers.

Similar studies have been conducted on Black River and its tributaries by Beadles (1972), Fowler and Harp (1974), Green and Beadles (1974), and Yeager and Beadles (1976) and on Sylamore Creek by Frazier and Beadles (1977).

METHODS AND MATERIALS

Collections were taken with the following equipment:

1) A 6-meter-long, .3-centimeter mesh minnow seine;
2) A gasoline-powered backpack shocker producing 230 volts with DC current; and
3) Hand held dip nets.

The electrofishing technique described by Ricker (1971) was used. The seine was primarily used to catch fish at the foot of a shoal area as they were washed downstream in front of the shocker. Hand held dip nets were used in all collection locations. Specimens were netted and fixed in 10% formalin for three to seven days, then washed, identified and preserved in 40% isopropanol.

Classification was accomplished with the keys of Pflieger (1975), Buchanan (1973), and Miller and Robison (1973). Genera and species are arranged alphabetically within each family in accordance with the scheme proposed by Greenwood et al. (1966). Scientific and common names of fishes follow those of Bailey et al. (1970).

RESULTS

This study yielded 28 species distributed among eight families. The following is an annotated checklist of the fishes of Rock Creek.

Petromyzontidae (Lampreys)

Lampetra aepyptera (Abbott). Least brook lamprey.
One specimen was captured during the spring collection and was found in a swift, shallow, rocky riffle. This record is a range extension of this species with the closest specimen recorded by Johnson and Beadles (1977) from the Eleven Point River system.

Cyprinidae (Minnows)

Campostoma anomalum pullum (Agassiz). Central stoneroller.
One specimen was collected just below Bubbling Spring during November, 1978.

Campostoma oligolepis Hubbs and Greene. Largescale stoneroller.
Very abundant in all collection sites.

Hybopsis amblops (Rafinesque). Bigeye chub.
Collected on the larger section of the creek. Uncommon.

Nocomis biguttatus (Kirtland). Hornyhead chub.
Collected in the pool section of the creek. This species was considered common.

Notropis cornutus chrysocephalus (Rafinesque). Striped shiner.
Common inhabitant of rocky pools; however, their occurrence was slightly below common. One specimen taken was 19.7 centimeters in length. Following Miller (1968), the writers consider *Notropis chrysocephalus* a subspecies of *Notropis cornutus* (Mitchell).

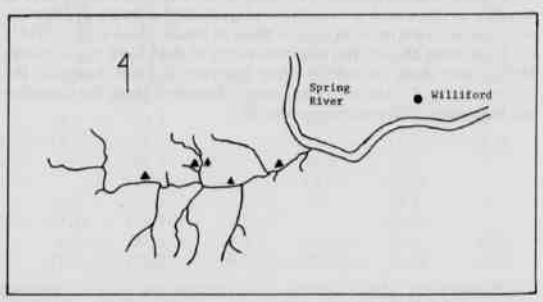

Figure 1. Collecting sites (▲) on Rock Creek, Sharp County, Arkansas. *Bubbling Springs.

Notropis galacturus (Cope). Whitetail shiner.
One specimen was found in the pool region of the lower section. This species is reported to be in the Spring River system by Buchanan (1973).
Notropis telescopus (Cope). Telescope shiner.
Abundant throughout the stream; however, mainly an inhabitant of pools over gravel bottoms.
Notropis zonatus (Putnam). Bleeding shiner.
Abundant throughout the stream, collected in all collection sites.
Chrosomus erythrogaster (Rafinesque). Southern redbelly dace.
Collected throughout the system mainly from flowing water over a rocky bottom.
Semotilus atromaculatus (Mitchill). Creek chub.
Common in the calm pools above riffles.

Catostomidae (Suckers)

Erimyzon oblongus (Mitchill). Creek chubsucker.
Common throughout the system. Found in the pool areas below riffles.
Hypentelium nigricans (Lesueur). Northern hogsucker.
The most abundant catostomid found in swift riffles and calm pools.
Moxostoma duquesnei (Lesueur). Black redhorse.
Very abundant during the spring collection; however, only common during the fall.

Ictaluridae (Catfishes)

Noturus exilis Nelson. Slender madtom.
Rare in occurrence. Most specimens were collected from swift riffles with a rock and gravel bottoms; however, one specimen was taken from a mud bottom area.

Cyprinodontidae (Killifishes)

Fundulus catenatus (Storer). Northern studfish.
Common throughout the system. Not as abundant as *Fundulus olivaceus*. Inhabitant of quiet pools over gravel bottoms.
Fundulus olivaceus (Storer). Blackspotted topminnow.
Widely distributed throughout the system but never in great numbers. Found in quiet pools over gravel bottoms as noted by Braasch and Smith (1965).

Centrarchidae (Sunfishes)

Ambloplites rupestris (Rafinesque). Rock bass.
A common inhabitant of deep pools. Found also under rock ledges in shoal areas.
Lepomis cyanellus Rafinesque. Green sunfish.
Common throughout the system. It was an inhabitant of the pool sections.
Lepomis megalotis (Rafinesque). Longear sunfish.
Found to be the most common of the bream. Inhabitant of the pool areas.
Micropterus dolomieui Lacepede. Smallmouth bass.
Found throughout the main creek system. Population was well established in all year classes.

Percidae (Perches)

Etheostoma blennioides Rafinesque. Greenside darter.
Common darter inhabiting the riffle areas.
Etheostoma caeruleum Storer. Rainbow darter.
One of the most abundant percids. Inhabitant of riffle and pools with gravel bottoms.
Etheostoma euzonum (Hubbs and Black). Arkansas saddled darter.
Abundant on the swift riffle areas of the lower section.
Etheostoma flabellare Rafinesque. Fantail darter.
Collected on shallow riffle areas. Moderately common throughout the system.
Etheostoma spectabile (Agassiz). Orangethroat darter.
Common throughout the system; however, found mainly along the head of riffle areas.
Etheostoma zonale (Cope). Banded darter.
Rare inhabitant. Found only at one location in a swift riffle area.

Cottidae (Sculpins)

Cottus bairdi Girard. Mottled sculpin.
Common in the upper section of the system. Collected in the swift riffle areas.

DISCUSSION

Rock Creek is an Ozark foothills stream that produces a fishable population of fish for the wading angler. The main sport species, *Ambloplites rupestris* (rock bass) and *Micropterus dolomieui* (smallmouth bass) were abundant. *Lepomis cyanellus* (green sunfish) and *Lepomis megalotis* (longear sunfish) were also present in sufficient number for the angler. During the survey of the fish population, sustaining reproduction was apparent in all species excluding *Lampetra aepyptera* (least brook lamprey), *Notropis galacturus* (whitetail shiner), and *Noturus exilis* (slender madtom). The record of *L. aepyptera* was a distributional record now placing it well within the Spring River system. *L. aepyptera* has been recorded from the Black River system by Yeager and Beadles (1976), from the White River system by Harp and Matthews (1975), and from the Sylamore Creek by Frazier and Beadles (1977).

Notropis telescopus (telescope shiner) and *Chrosomus erythrogaster* (southern redbelly dace) dominated the family Cyprinidae. *Notropis galacturus* is reported common in the Spring River system; however, only one specimen was collected in Rock Creek. Of the family Catostomidae, *Hypentelium nigricans* (northern hogsucker) was found throughout the system; however, it did not appear to be overpopulated. *Moxostoma duquesnei* (black redhorse) was more abundant during the spring collection. The catfish family, Ictaluridae, was not well represented, with only a few specimens of *Noturus exilis* found. The reason for this is expected to be due to the heavy predator population present. *N. exilis* has been found to be common in neighboring Ott Creek in which only *L. cyanellus* exists as the predator population (pers. obs. by Carter).

Fundulus catenatus (northern studfish) and *Fundulus olivaceus* (blackspotted topminnow) were common over most of the system. The family Percidae was well represented with abundant numbers of *Etheostoma blennioides* (greenside darter), *Etheostoma caeruleum* (rainbow darter), *Etheostoma euzonum* (Arkansas saddled darter), *Etheostoma flabellare* (fantail darter), and *Etheostoma spectabile* (orangethroat darter). *Etheostoma zonale* (banded darter) was rare. Specimens of *Etheostoma blennioides* ranged to 13 centimeters. The darters were mainly in the upper two-thirds of the stream where the water flowed over more riffle areas and was more shallow.

Cottus bairdi (mottled sculpin) of the family Cottidae was also more abundant in the upper section of the system. All age classes were present with the largest adult collected being 10.5 centimeters in total length.

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CONTAMINATION OF BOONE-ST. JOE LIMESTONE GROUNDWATER BY SEPTIC TANKS AND CHICKEN HOUSES

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ABSTRACT

Eighty-one water samples were collected from wells in the Boone-St. Joe limestone aquifer of northwest Arkansas and analyzed for fecal coliform, fecal streptococcus, total coliform bacteria, chloride, phosphate, nitrate and sulfate to determine the degree of contamination. Forty-nine percent of the samples had fecal streptococcus counts greater than 1 colony per 100 ml, 68% had total coliform counts of 1 or more colonies per 100 ml, and 9% of the wells had fecal coliform counts of 1 or more colonies per 100 ml.

Water from wells in Clarksville, Nixa, Noark, Tonti and Waben cherty silt loam soils showed from 83 to 100% bacterial contamination. Nitrate concentrations exceeded 45 ppm in 80% of the wells in Waben soils and in 50% of wells in Nixa soils, with wells in the other soil types having nitrate concentrations of less than 45 ppm. Nitrate, sulfate, and chloride concentrations were all found to be statistically related. Wells closest to chicken houses were found to have statistically greater choloride concentrations. Chloride was also found to be statistically greater in wells with shallow casing. Wells within 150 meters of a photo-lineament were found to have greater fecal coliform contamination than wells farther away. The results indicate the ease at which wells can be contaminated with only shallow casing, in cherty soils, and/or near chicken houses or fractures (photo-lineaments).

INTRODUCTION

The Boone-St. Joe limestone aquifer, an important unconfined aquifer for the residents of rural Benton County, Arkansas, is particularly susceptible to contamination due to the nature of karst hydrology and soil genesis in karst terranes. Although the occurrence and movement of groundwater in karst aquifers are not completely understood, it is generally conceded that water movement principally occurs through fractures, joints, bedding planes, and conduits that have been enlarged by solution (Hamilton, 1947, Davis and DeWiest, 1966). Pollution of the Boone-St. Joe aquifer of northwest Arkansas has been amply documented. Keener (1972), Coughlin (1975), Wagner et al., (1976), and Brooks (1979) all have found bacterial contamination of the area wells. Keener (1972), Brooks (1979), and Willis (1978) also found many wells to be contaminated with respect to chloride (Cl^-), sulphate ($SO_4^=$), phosphate ($PO_4^=$) and nitrate (NO_3^-).

Description of the Study Area: The study area (Fig. 1) is entirely within Benton County, Arkansas, and it is bounded to the north by the Arkansas-Missouri state line; to the south by the Washington-Benton County line; to the west by the Arkansas-Oklahoma state line; and to the east by Beaver Reservoir. The study area is on the Springfield Plateau province of the Ozark Highlands, and it is completely underlain by the Boone and St. Joe limestones of Mississippian age except in those places where stream dissection has cut below the St. Joe to expose older formations. The Devonian Chattanooga Shale is of hydrogeologic significance as it forms an impermeable boundary that perches water within the overlying unconfined Boone-St. Joe limestone aquifer.

In addition to the random sampling of wells throughout the county, well samples were collected from three small chicken farming communities in southeast Benton County, Arkansas (Fig. 2).

METHODS AND MATERIALS

Whenever possible, samples were collected at outdoor faucets nearest to the wells; other samples were collected at indoor faucets.

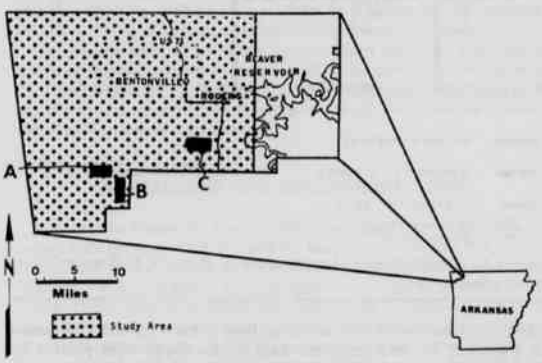

Figure 1. Location of study areas in Benton County, Arkansas, showing location of areas A, B and C.

In all cases, a representative sample was obtained by running the faucet for a minimum of 5 minutes so that all samples were taken while the well pumps were operating. Faucets were flame sterilized before sampling to reduce the possibility of sample contamination by the faucet. Sample sizes of 300 ml were taken for bacterial analyses and stored immediately on ice. Samples were analysed the same day for total coliform (TC), fecal coliform (FC), and fecal streptococcus (FS) bacteria. Bacteria were isolated by the membrane filter technique (APHA, 1976). Two plates were cultured for each sample and for each bacteria type corresponding to filter volumes of 10 and 50 ml. Colonies were cultured and counted using the media, incubation conditions, and enumeration techniques described in *Standard Methods for the Examination of Water and Wastewater* (APHA, 1976).

Chemical analyses were made for nitrate (NO_3^-) sulfate ($SO_4^=$), chloride (Cl^-) and phosphate ($PO_4^=$) using standard methods modified by Hach (Hach Chemical Co., 1975). Chemical analyses were

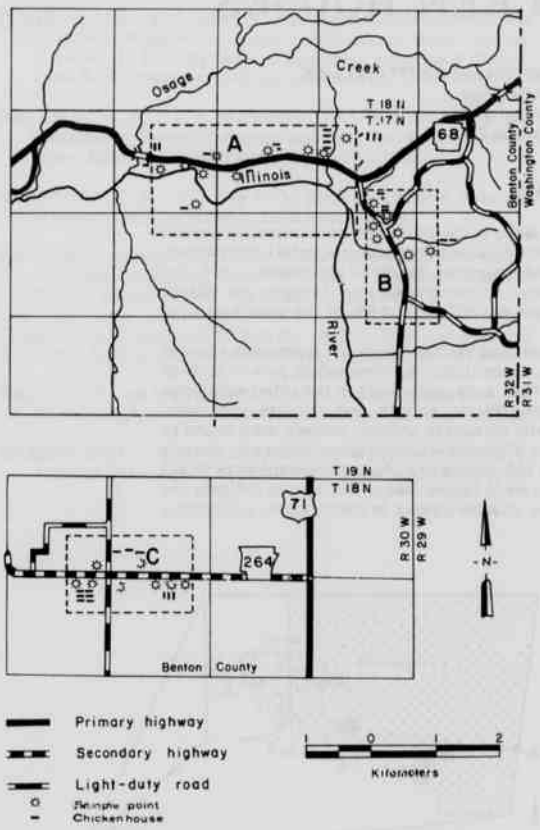

Figure 2. Detailed map of study areas A, B, and C in Benton County, Arkansas.

performed only on 29 samples taken from areas A, B and C as shown in Figure 2. Photo-lineaments used in this study were plotted by Rezaie (1979) using black-and-white low altitude photographs with a scale of 1:20,000 and color IR, U2, 1:120,000 scale photographs. Distances from the sample points to the nearest chicken house and photo-lineament were measured as the straight-line distance using 7.5 minute topographic quadrangle maps and a ruler. Soil types were determined using 1:20,000 scale soil type types from the *Soil Survey of Benton County, Arkansas* (USDA, 1977). All statistical analyses were executed by Statistical Analysis System (Barr et al., 1979) computer techniques.

RESULTS

Bacterial Analyses: Although TC, FC, and FS bacteria are not a direct threat to public health, their presence in drinking water and the implication of fecal contamination, especially for FC and FS, are adequate causes for alarm. Therefore the USEPA (1976) has recommended drinking water limits such that coliform bacteria (FC, TC) should have counts of less than 1 colony per 100 ml. A large number of wells sampled exceeded the USEPA recommended levels for FC and TC bacteria (Table 1). Samples analysed for TC had the following results: 1) 68% ($^{45}/_{66}$) had counts of one or more colonies per 100 ml and 2) 20% ($^{13}/_{66}$) had counts of 100 or more colonies per 100 ml. Of wells sampled, 9% ($^{6}/_{62}$) had FC counts of one or more colonies per 100 ml. Fecal streptococcus counts greater than 1 colony per 100 ml were found in 49% ($^{20}/_{41}$) of the wells.

From the bacterial analysis of 50 wells and springs (presumably in small communities in Washington and Benton counties of Arkansas), Keener (1972) reported that: 1) 42% had FS counts of 1 or more colonies per 100 ml, 2) 74% had FC counts greater than 1 colony per 100 ml, 3) 20% had TC counts greater than 100 colonies per 100 ml, and 4) 16% had FC counts of one or more colonies per 100 ml. Coughlin (1975) investigated a 100 sq mile area in northcentral Washington County, Arkansas, and reported that TC bacteria were present in 80% of 61 well and spring water supplies sampled. Therefore the results of Keener (1972) and Coughlin (1975) are in agreement with this study in demonstrating that the Boone-St. Joe aquifer is grossly contaminated with respect to bacteria levels.

Table 1. Results of bacterial analyses of water samples from wells in Benton County, Arkansas.

Bacterial Group	Number of Samples	Range (colonies / 100 ml)	Mean (colonies / 100 ml)	Std. Dev. (colonies / 100 ml)
FC	63	0 - 170	3.2	21.5
FS	43	0 - 530	28.9	86.0
TC	66	0 - 780	69.4	154.5

Chemical Parameters: Chloride (Cl^-) may be regarded as a pollution indicator in carbonate terranes (Nutter, 1973). In unpolluted limestone areas, the Cl^- concentration rarely exceeds 35 ppm, and it is commonly much lower (Hem, 1970). The USEPA (1976) recommends an upper limit of 250 ppm Cl^- in drinking waters. Chloride concentrations of 29 wells sampled in areas A, B, C, (Fig. 2) ranged from 2 to 44 ppm with a mean value of 14 ppm and a median value of 10 ppm (Table 2). Therefore, the groundwater is essentially uncontaminated with this ion.

Nitrate (NO_3^-), phosphate ($PO_4^{=}$) and sulfate ($SO_4^{=}$) are also commonly used as indicators of ground water quality. The USEPA (1976) recommended limits for NO_3^- and $SO_4^{=}$ in drinking water are 45 ppm and 250 ppm, respectively. No limit has been established for $PO_4^{=}$. In the 29 wells samples in areas A, B, and C, NO_3^- concentrations ranged from 1 to 96 ppm with a mean value of 29 ppm and a median value of 21 ppm (Table 2). Of those wells, 24% ($^{7}/_{29}$) had NO_3^- concentrations greater than 45 ppm.

Sulfate concentrations ranged from 0 to 47 ppm with a mean value of 13 ppm and a median value of 11 ppm. Phosphate concentrations ranged from 0.2 ppm to 3.2 ppm (Table 2). For the wells in areas A, B, and C the NO_3^-, Cl^-, and $SO_4^{=}$ concentrations are statistically correlated at $\alpha < 0.10$. This indicates that the concentrations of these anions are expected to increase together since a single pollution source is likely to contribute all of these ionic species. Willis (1978) and Brooks (1979) reported similar correlations.

Soil Relationships: The soil types found in the study area and the percentages of contaminated wells found in each type are given in Table 3. Wells were judged to be contaminated if the FC, FS or TC counts were 1 colony or greater per 100 ml. An examination of *Soils Survey of Benton County, Arkansas* (USDA, 1977) reveals that all soil types in the county suffer moderate to very severe limitations for

Table 2. Results of bacterial and chemical analyses of water samples taken from 29 wells in areas A, B, and C in Benton County, Arkansas.

Variable	Number of Samples	Range	Mean	Std. Dev.
Well Depth ft.	23	14 — 1000	178	222.5
FC col./100 ml	14	0 — 15	1.4	4.1
FS col./100 ml	8	0 — 56	15.9	19.4
TC col./100 ml	12	0 — 760	93.6	228.7
NO_3^- p.p.m.	29	1.3 — 96.3	29.0	26.4
PO_4^- p.p.m.	29	0.20 — 2.37	0.72	0.61
Cl^- p.p.m.	29	1.5 — 43.5	14.2	11.8
$SO_4^=$ p.p.m.	29	0.0 — 47.0	13.1	11.8

Table 3. Bacterial contamination of well water samples with respect to soil type.

Name	Symbol	Description	% contaminated
Britwater	BtC	gravelly silt loam	100% (2/2)
Captina	CnB	silt loam	57% (4/7)
Clarksville	CuF	cherty silt loam	100% (4/4)
Elsah	Eg	cherty silt loam	100% (1/1)
Enders	Eof	stony loam	100% (1/1)
Healing	He	silt loam	— (0/0)
Linker	LrC	fine sandy loam	100% (1/1)
Nixa	NfC	cherty silt loam	86% (6/7)
Nixa	NfD	cherty silt loam	83% (5/6
Noark	NoD	cherty silt loam	100% (1/1)
Noark	NoE	cherty silt loam	100% (1/1)
Noark	NoF	cherty silt loam	75% (3/4)
Peridge	PeB	silt loam	100% (2/2)
Peride	PeC	silt loam	100% (1/1)
Secesh	Se	gravelly silt loam	17% (1/6)
Tonti	TsC	cherty silt loam	88% (14/16)
Waben	WeC	cherty silt loam	100% (1/1)

the safe operation of septic tank filter fields. Based on the results of this study, it is inferred that a large number of septic tank systems in the area do not function adequately. Water from wells located in cherty silt loam soils (Clarksville, Nixa, Noark, Tonti and Waben) had the highest percentages of contamination. Water from wells in Secesh and Captina silt loams had the lowest relative contamination. This difference may be due to the presence of chert as indicated in a study by Stafford (1979). His results indicated increased permeability of soils with chert when compared with expected permeabilities of silt loams not containing chert.

Statistical Relationships: The Spearman Rank Correlation (Siegel, 1956; Barr et al., 1979) procedure was applied to the data to test the following relationships for statistical significance: 1) bacterial counts vs proximity to photo-lineaments, and 2) bacterial counts vs proximity to chicken houses. The Spearman Rank Correlation procedure was also applied to the data from areas A, B and C to test the following relationships for statistical significance: 1) bacterial and chemical results vs chicken house proximity, 2) bacterial and chemical results vs well depth, and 3) bacterial and chemical results vs well casing depth.

Wells within 150 m of photo-lineaments were found to have greater FC counts (correlation, $\alpha = 0.109$), but not the wells of 300 m; however, this initial correlation is based on only 6 FC counts of 1 colony or greater per 100 ml. Statistically significant correlations were not found for FC, FS, and TC counts and chicken house proximity within 150 m or 300 m. Keener (1972) found no significant relationships between TC counts and wells within 50 ft of septic tanks.

Chloride concentrations were statistically greater in wells near chicken houses based on 29 observations (correlation, $\alpha = 0.08$), and in wells with shallow casing based on 11 observations (correlation, $\alpha = 0.05$). No other significant correlations were found.

The general lack of statistical relationships may be a function of the poor reproducibility of defined photo-lineaments (Podwysocki, 1975 and Siegal, 1977), lack of information on where chicken wastes are stored and spread in relationship to nearby wells, and/or possibly the small number of wells sampled.

CONCLUSIONS AND RECOMMENDATIONS

Wells of the Boone-St. Joe aquifer show a high degree of contamination with respect to FS, FC and TC bacteria counts and NO_3^- concentrations as the results of this and previous studies demonstrate (Keener, 1972; Coughlin, 1975; Wagner et al., 1976; Brooks, 1979; Willis, 1979). Poultry manures and septic tank systems are the most ubiquitous possible sources of pollutants entering the groundwaters of rural Benton County. A high percentage of wells were found to be contaminated with FS and TC bacteria both near to and far from chicken houses. This suggests that many wells are being contaminated by septic tank systems, surface runoff or both. However, heavy applications of manure some distance from chicken houses but in the vicinity of a recharge zone (such as a sink hole) can cause considerable groundwater contamination.

Photo-lineaments do not appear to have a controlling influence on hydrologic properties (Rezaie, 1979) or to have a relationship to groundwater contamination in the Boone-St. Joe aquifer. The lack of correlations between photo-lineaments and contaminates may be due to inaccuracies in the definition of photo-lineaments. The relationship of well contamination to soil type indicates that wells in cherty soils are highly susceptible to contamination. A detailed investigation of soil characteristics and degree of contamination is strongly suggested.

As preventative measures, residents of rural Benton County, Arkansas, should consider a greater spacing of wells and septic tank filter fields (Keener, 1972), modifications of the standard filter field design (Stafford, 1979), and routine monitoring of groundwater quality. Deeper casing depth in wells is also recommended as a means to lessen the probability of contamination.

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THE EFFECT OF COLD SHOCK ON THE METABOLISM OF *TRICHOMONAS GALLINAE*

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ABSTRACT

The influence of cold (4°C) used to prepare cells for metabolic investigations was examined with *Trichomonas gallinae* in this study. Cells washed with cold diluent in a refrigerated centrifuge were found to be less stimulated in their gas production at 37°C when exposed to glucose or maltose than cells washed at room temperature conditions. Such cold-prepared cells had higher initial glycogen contents after washing, faster endogenous glycogen degradation rates when incubated at 37°C, but lower glycogen synthesis in the presence of glucose or maltose when compared to cells not prepared in the cold. However, uptake of glucose and maltose at 37°C was not affected by pretreatment with cold. Washing with cold also reduced the total number of recoverable cells by an average of 20%. Cold washing of *T. gallinae* in three diluents (modified Ringers, Krebs Ringer phosphate, and 2% Trypticase) increased the recovery or lag time in STS medium when compared to use of the three washing diluents at room temperature.

INTRODUCTION

Cold shock is defined as injury or death to organisms caused by sudden chilling without freezing (MacLeod and Calcott, 1976). Cold shock is at times unintentionally caused in biological studies when there is such a chilling of living material to preserve metabolic stasis. In initial studies of carbohydrate utilization by *Trichomonas gallinae*, a pathogenic protozoan parasite of birds, it was noted that this organism responded poorly to exogenous carbohydrates in respirometry experiments. The cells had been prepared for experimentation by a washing and centrifugation procedure that was maintained at approximately 4°C until the cells were tested. It was suspected that this procedure may have been responsible for poor stimulation by sugar substrates. Therefore, cells from the same culture batch were divided into 2 groups with one receiving a cold-washing pretreatment as before and the other group of cells prepared under room temperature conditions. The two groups of cells were compared as to the effect of glucose and maltose on gas production, disappearance of these two substrates from suspension fluid, and changes in intracellular glycogen content. The effect of the two treatments on recovery in a minimal growth medium was also studied.

MATERIALS AND METHODS

The Jones' Barn strain of *Trichomonas gallinae* was used in this study and was maintained in culture using CPLM medium with 5% (final vol.) inactivated human serum. Cells for experiments were grown to a population density of $1-2 \times 10^5$ trichomonads/ml after approximately 24 hr incubation at 37°C. The medium, usually a one liter volume, was then divided into two equal portions, "A" and "B." Cells in "A" portion were centrifuged at 1000 g and washed three times with Krebs-Ringer Phosphate diluent (KRP) at room temperature. The KRP was 20 mM at pH 7.0, and prepared according to Umbreit et al. (1951). Cells in "B" portion were centrifuged at 2000 g in a refrigerated centrifuge (4°C) and washed with ice cold KRP diluent. International model CS (room temperature) and Lourdes Betafuge model A (cold) centrifuges were used. After the final washing, cells were resuspended in KRP and cell concentrations determined with a hemocytometer. Cell suspensions were then distributed to Warburg vessels and allowed to equilibrate to 37°C for 15-20 min.

Gas production was measured by the direct method of Warburg (Umbreit et al., 1951) using two flasks for determination of CO_2 and H_2. Since *T. gallinae* is a facultative anaerobe, the gas phase was 99.9% N_2; and this was obtained by flushing the flasks for 15 min. Endogenous flasks contained no carbohydrate whereas substrate flasks contained 0.2 ml of substrate in one side arm. When tipped into the cell suspension in the center compartment, final sugar concentration was 10 mM. Perchloric acid (70%) in the other sidearm was used to determine bound CO_2. The concentration of the organisms in the flasks was approximately 50 million cells/flask.

Substrate disappearance was measured on the supernatant of centrifuged Warburg flask contents by reducing sugar value (Nelson, 1944). Glycogen content of the centrifuged cell pellet was measured by the method of Good et al. (1933). Flask contents used for substrated uptake and glycogen content were not exposed to perchloric acid.

The recovery of cold-shocked cells in growth medium was studied using STS medium (Kupferberg et al., 1948) inoculated with cells from different treatment regimens which were as follows: Cells from 170 ml of a 48 hr old CPLM culture were centrifuged at low speed (500 g). The supernatant was decated, and the pellet resuspended in 10.0 ml of fresh CPLM medium. One ml of this mixture was added to 40 ml of six different sterile diluents. The six tubes of diluents were: 1) cold modified Ringers (Trussel and Johnson 1943), 2) cold KRP, 3) cold 2% Trypticase (BBL laboratories) and 4,5,6) room temperature tubes of these same three diluents. The cells in each tube were washed and centrifuged three times at their respective temperatures and samples from the final suspension inoculated into STS medium which was then incubated at 37°C. Growth was followed by hemocytometer counts of samples taken at predetermined intervals.

RESULTS

During a study of metabolic gas production by *T. gallinae*, the organisms were subjected to a pretreatment consisting of washings with cold KRP in a refrigerated centrifuge at 4°C. The purpose of this pretreatment was to maintain the organisms as close as possible to their original metabolic state when separated from the culture medium. Results were not in agreement with Read (1957), and it was noted that Read did not employ low temperatures in the preparation of his cells. Therefore a batch of organisms was divided into two parts with one receiving a cold treatment and the other room temperature treatment before experimentation (pretreatments). The effect of glucose and maltose on gas production of the two types of pretreatment can be seen in Table 1. Cold-treated cells showed less stimulation above the endogenous rate than room-temperature cells with both glucose or maltose as substrates. However, absolute values for en-

dogenous gas production (not noted in Table 1) were higher for cold-washed cells.

The ability of glucose and maltose to stimulate glycogen production was greater in the room temperature-washed cells (Table 2). The rate of endogenous glycogen depletion was greatest in the cold-treated cells. The percent change in glycogen content was calculated based on the endogenous rate of depletion for each treatment as 100%. In all four experiments maltose stimulated greater glycogen production in room temperature-treated cells than in cells prepared at 4°C. Glucose gave a major glycogen sparing advantage in two experiments for room temperature cells but no advantage in the two other experiments.

The disappearance of glucose and maltose from the supporting medium was also measured in paired experiments. The results of five experiments showed no significant differences in uptake of the sugars (per mole) between cold and room temperature treatments. Based on micromoles of substrate consumed/hour/10^8 cells (S.E.), 7.3 ± 1.4 mM glucose were taken up by cold-treated cells and 6.5 ± 2.3 mM by room temperature treated cells; 6.2 ± 2.1 and 8.0 ± 1.7 mM of maltose were taken up by cold- and room temperature-treated cells, respectively.

During the course of these experiments, it was noted that cold harvesting yielded fewer organisms than room temperature harvests. The data from paired experiments were analyzed for this effect. In each experiment cultures were pooled and divided into two equal portions. After respective pretreatment, the final pellet was brought to a convenient volume for dilution and cells counted. In each of six experiments there was a greater recovery of cells with room temperature treatment than with cold. The percent differences in population in each of these experiments were: 10% (1 experiment), 30% (1 experiment), and 19% (4 experiments). Use of the binomial expansion method shows that the probability of these differences occurring randomly is less than 2%. Cold pretreatment results in a destruction of organisms as well as their dimenished metabolic capability.
ity.

Utilizing the same method of dividing the cells for pretreatment, the glycogen content of the cells after the pretreatments was examined. In all five experiments glycogen content was higher in cells pretreated with cold (Table 3). Apparently some glycogen is degraded by *T. gallinae* at room temperature during washing and centrifugation but is spared with maintenance of cells at low temperature.

Table 1. The effect of pretreatment on metabolic gas production of *Trichomonas gallinae*. (Figures expressed as percent above endogenous.)

	10 mM Glucose[1]		10 mM Maltose	
Pretreatment	CO_2	H_2	CO_2	H_2
Room temperature	100	25	87	98
Cold temperature	3	8	60	12

[1]Average of three experiments.

In growth recovery experiments three diluents were used for the washing procedures: modified Ringers, Krebs-Ringer phosphate (KRP), and 2% Trypticase solutions. It was thought that certain diluents might have a protective effect against cold shock and that this might be detected in growth recovery. Modified Ringers is a minimal salt solution. The KRP and 2% Trypticase were at pH 7.0 and could act as buffers. The 2% Trypticase contains amino acids and peptides that might be lost from the cells as a result of washing. Also, it was expected that any changes in the growth curve would be seen in the lag and early log phases. Therefore a heavy inoculum of cells was used to insure accurate counts in the initial growth phases.

Table 2. The effect of pretreatment on the synthesis of glycogen from glucose and maltose by *Trichomonas gallinae*. Unclosed values represent mg change in glycogen content after 1 hr incubation. Closed values are percent glycogen change based on endogenous change as 100%.

Experiment	Mg of glycogen synthesized/10^8 cells/hr		
	Endogenous	Glucose	Maltose
1			
Cold	-0.77	-0.31 (159%)	+0.13 (217%)
Room Temperature	-0.33	-0.17 (148%)	+0.91 (375%)
2			
Cold	-0.97	-1.14 (72%)	-0.34 (160%)
Room Temperature	-0.86	-0.32 (162%)	+0.24 (227%)
3			
Cold	-1.20	-1.20 (100%)	-1.40 (83%)
Room Temperature	-0.50	+0.20 (240%)	0.00 (200%)
4			
Cold	-0.52	-0.32 (138%)	-0.47 (143%)
Room Temperature	-0.54	-0.37 (132%)	+0.26 (250%)

Table 3. Initial glycogen content of *Trichomonas gallinae* after pretreatment washing at room and cold temperature KRP (pH 7.0). Figures represent mg glycogen/10^8 cells.

Pretreatment	Experiments				
	1	2	3	4	5
Cold	3.06	4.82	5.26	7.20	4.47
Room Temperature	2.56	3.88	4.61	6.10	3.91

A typical experiment is seen in Figure 1 with modified Ringers used as the diluent. An increase in the lag phase is seen with the cold-treated cells and the population difference continues to 24 hr. Using KRP or 2% Trypticase did not change this effect to any marked degree since the curves obtained were quite similar to those seen in Figure 1. Using total cell counts as the criterion for population size, a slower recovery period was indicated after cold washing of cells.

DISCUSSION

Cold shock was first reported by Sherman and Albus (1923) in a bacterium, *Escherichia coli*. Most of what is known about cold shock has come from studies with bacteria, especially gram-negative organisms, but the phenomenon has been described from a variety of microbes and eucaryotic cells. The changes that occur with cold shock are varied and complex but are primarily associated with increases in membrance permeability and loss of substances from the shocked cells. A number of low molecular weight solutes such as amino acids, nucleotides, small proteins and low molecular weight peptides have been found to be released from shocked cells. Presumably, it is the loss of these compounds that causes death or reduced metabolic capabilities of the affected cells. Important variables are cell age, diluent (milieu), growth and recovery medium, presence of cations ($Mg++$, $Ca++$, $Mn++$), and rate of cooling, all of which may increase or decrease the effectiveness of cold shock. These aspects of cold shock in microorganisms have been summarily reviewed by MacLeod and Calcott (1976). Permeability changes in cold shock are believed due to a phase transition in the membrane lipids

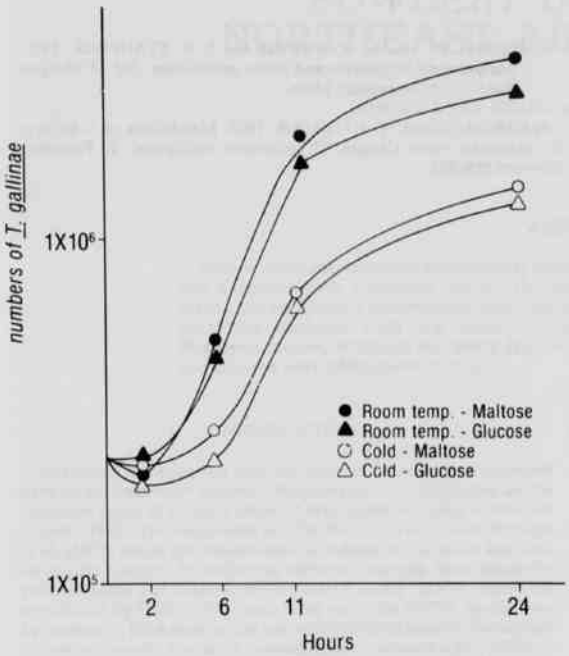

Figure 1. The effect of cold and room temperature pretreatment washings of *Trichomonas gallinae* with modified Ringers' solution on subsequent recovery in STS growth medium (pH 7.0). Sugar concentrations are 20 mM.

from a liquid to a solid state. Adam (1941) showed that macromolecular films of lipids will shrink upon cooling with a temperature range for each lipid. Salts of long-chain fatty acids will form microcrystals at a specific temperature known as the Kraft point (Dervichian, 1965). A sudden change in configuration of the lipids in the cell membrane should express itself as changes in permeability mechanisms. Steim et al. (1969) have suggested that such changes create hydrophilic channels allowing the escape of solutes from cells.

Cold shock effect on the viability of *Trichomonas gallinae* was demonstrated on logarithmic cells in experiments performed after the present study (Matthews and Daly, 1974). Using a colony count technique, cells exposed to slow cooling in modified Ringers showed a higher initial percent viability than cells exposed to sudden chilling. In allowing the cells to remain at 4°C, the death rate was greater with the slowly cooled cells. Little loss in viability was seen after the initial decrease with suddenly cooled cells. In the present study stationary phase cells were used which are usually more refractile (in bacteria) to cold shock (Meynell, 1958). There was an initial loss of these older cells in the cold-washing procedure indicating cold-sensitive cells had been present and had presumably disintegrated. Recovery in growth medium was slower with cold-washed cells with an increased lag phase. Unfortunately, no reliable viability test was available for these experiments at the time; therefore, it is possible that the increased lag seen may be due in great part to dead cells in the total cell count rather than slowly recovering cells. Three diluents were used to wash the cells for these growth experiments, since bacterial studies had shown the importance of the presence or absence of common cations and amino acids. No major differences in "recovery" of the cells were noted among the use of the three diluents.

In preliminary metabolic studies with *T. gallinae*, it was not suspected that the employment of a cold-washing procedure would adversely affect the condition of the cells. Microscopic examination of trichomonads kept at 4°C for up to 1½ hr showed no apparent decrease in motility when warmed to room temperature. Cold washing of parasitic protozoa in experimental preparation procedures is not generally done; therefore, these findings were somewhat fortuitous and unique. Warren and Kitzman (1963) noted that cold washing of *Schizotrypanum cruzi* resulted in a higher level of oxygen consumption but attributed this to cold preservation of available intracellular endogenous substrate. In the present study a greater glycogen pool was maintained in cold-washed cells, and subsequent endogenous gas production was higher than with room-temperature cells. However, stimulation of CO_2 and H_2 by exogenous glucose and maltose was greater with room temperature-treated cells. It may be argued that this is not evidence for a metabolic defect, since stimulation of cold-washed cells would appear to be lower only because the higher relative endogenous rate would result in a proportionally lower stimulation to the two sugars. The equimolar uptake of carbohydrate after both treatments would also appear as evidence against cold shock, especially since membrane permeability is a target of this effect. Glycogen metabolism, however, is noticeably changed since cells exposed to cold are less able to synthesize this polysaccharide. Endogenous depletion of glycogen at 37°C is higher for cold-washed cells. This may reflect an increased intracellular inorganic phosphate level due to permeability changes stimulating glycogen phosphorylase activity.

Observations of cold shock on the metabolism and recovery in growth medium of *T. gallinae* have been made in this study, but the mechanisms of this effect are not clear. However, it is obvious that cold treatment of this organism will result in greatly different physiological data than that from cells prepared under less drastic temperature changes. Cold shock should be avoided with trichomonads unless it is to be studied intrinsically or for examination of defective metabolism.

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THE DISTRIBUTION OF *NAEGLERIA FOWLERI* IN SELECTED NORTHEAST ARKANSAS LAKES

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ABSTRACT

Seven northeast Arkansas recreational lakes were examined for the presence of pathogenic and nonpathogenic *Naegleria fowleri*. Cultural differentiation and microscopic morphology were used as species determining tests, while mouse pathogenicity tests were conducted to determine virulence. Only one isolate met all criteria utilized for definite identification of *Naegleria fowleri*, although *Naegleria* type organisms were found in all of the lakes. None of the isolates were pathogenic in mice.

INTRODUCTION

Increasing attention has been directed to the recently discovered pathogenic freshwater amoeba, *Naegleria fowleri*, implicated as the causative agent of primary amoebic meningoencephalitis in humans (Carter, 1972). De Jonckheere and De Voorde (1977a) and Wellings et al. (1977) found that environmental isolates of *Naegleria spp.* can be readily cultured by collecting sediment samples from thermally polluted lakes and streams. By the use of varied culture conditions established by Griffin (1972) and Weik and John (1977), species can be separated. Both smaller size and cultural fastidiousness distinguish *N. fowleri* from *N. gruberi*, a nonpathogenic species (Carter, 1972).

De Jonckheere (1977) reported that both pathogenic and nonpathogenic strains of *N. fowleri* exist and that pathogenic strains were almost invariably associated with nonpathogenic variants. Most distribution studies with pathogenic strains have involved water reservoirs that received thermal effluent which raised the water temperature, creating conditions favorable for the growth of *N. fowleri*. Relatively little is known about its distribution in temperate climate reservoirs which only seasonally reach favorable temperatures. However, Wellings et al. (1977) isolated *N. fowleri* from several Florida lakes which were subject to seasonal temperature fluctuations. They demonstrated that the organisms can overwinter in lake bottom sediments at temperatures as low as 12°C. Bone and Becker (1975) reported negative results from isolation attempts employing surface water samples from recreational lakes in western Arkansas.

The purpose of the current study was to determine if *N. fowleri* was present in several northeast Arkansas lakes. Sediment samples were collected during seasonal warm temperatures and processed for use in differential cultivation, microscopic examination and mouse infectivity.

MATERIALS AND METHODS

Two strains of *N. fowleri*, LEE and HB-4, were obtained from D.T. John *(per. comm.)*. These were used for comparison purposes and as cultivation controls.

Seven lakes in northeast Arkansas were selected as sampling sites because of frequent use by the public, and the variety of ages, depths, sizes and sediments. The seven lakes were Lake Charles, Lake Frierson, Lake Hogue, Craighead Lake, Lake Poinsett, Big Lake and Mallard Lake. Five of the lakes have restricted use and do not allow swimming. Both Lake Charles and Craighead Lake permit swimming in specified areas, while water skiing is also allowed on the remainder of the latter lake. All the lakes were man-made, with the exception of Big Lake, and none receive significant thermal effluent.

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Sediment samples were taken at the mud-water interface. Samples from depths less than 62 mm were simply scooped up in 400 ml biological specimen jars, while deeper samples were collected by the use of an Eckman dredge, 21 X 21 cm (Wildlife Supply Co., Saginaw, Michigan). Subsurface water and sediment were separated and placed in 400 ml biological specimen jars. The water temperature was immediately taken, and some of the water was mixed with the sediment to form a muddy slurry. All samples were processed in the laboratory on the day of collection. The pH of the mud slurry was determined with an electronic pH meter immediately upon opening the jars.

The procedure described by Wellings et al. (1977) was followed, with modifications, for the processing of samples. The samples were washed with 100 ml of 1% beef extract. After vigorous shaking, heavy material was allowed to settle, and the supernatant fluid was centrifuged at 500 X G for 30 minutes. The resulting supernatant was discarded, and the pellets were resuspended in 25 ml of 1% beef extract and centrifuged at 500 X G for 15 minutes. The supernatant was again discarded, and the pellets were placed on 15 ml non-nutrient agar bearing a heavy suspension of *Escherichia coli* (NNE) (De Jonckheere and De Voorde, 1977b). These were incubated in petri dish cans with lids at 30 and 45°C, the latter temperature reportedly being inhibitory to *N. gruberi* and some nonpathogenic *N. fowleri* (De Jonckheere and De Voorde, 1977b). Plaque-forming cultures were transferred and maintained on NNE by removing a 1 X 1 cm piece of agar from the dense ring of migrating amoebae and placing it on a fresh NNE plate. Transfers were also made to a modified Nelson's medium containing 0.1% (w/v) liver concentrate (Sigma Chemical Co.), 0.1% (w/v) glucose and 2% (v/v) fresh rabbit serum in Page's saline (Page, 1967), pH 6.5 in screw-cap culture tubes and incubated at 30°C (Weik and John, 1977).

An attempt was made to suppress nonpathogens to an even greater extent by increasing the incubation temperature as suggested by De Jonckheere and De Voorde (1977b) and Griffin (1972). Mixed isolates exhibiting characteristics of *N. fowleri* were incubated at 40°C on NNE for 7-10 days and examined daily for plague formation.

Wet mount microscopic examinations of trophozoites and cysts were made with a Wild phase-contrast microscope to determine the type of movement and cyst wall morphology. The ability of the organisms to flagellate was also observed microscopically. One drop of amoeba suspension was mixed with two drops of deionized water, incubated at 42°C and viewed at 30 min. intervals for the formation of biflagellates. In order to more critically examine the trophozoites for nuclear detail and the cysts for pore structure, permanent slides were prepared with iron-hematoxylin stain according to the method outlined by Spencer and Monroe (1961).

Isolates which exhibited characteristics of typical *N. fowleri* were utilized in mouse pathogenicity studies. Washings of active plaques on NNE were made with Page's saline, and the number of tropho-

zoites per ml was determined by the use of a Levy hemocytometer. Amoeba suspensions containing 1.0 X 10^8 to 1.1 X 10^7 trophozoites per ml were used to infect mice. Young white mice were anesthetized with ether and inoculated intranasally with 0.02 µl of the suspension. Three weanling mice were injected intracranially with 0.02 µl of amoeba suspension. All mice were observed for 14 days for reactions indicative of meningoencephalitis. Any mice which died or were sacrificed after exhibiting a reaction were autopsied and the brain examined microscopically for amoebae. All other mice were euthanized after 14 days.

Identification of isolates as *N. fowleri* was based on criteria provided by De Jonckheere et al. (1975) and De Jonckheere and De Voorde (1977b). These criteria are summarized as follows:

1. Ability to grow at 45°C.
2. Morphological features: A large karyosome surrounded by clear zone, a fine nuclear rim, a single contractile vacuole and eruptive, finger-like pseudopodia are typical of *N. fowleri*.
3. Flagellation test at 42°C: *N. fowleri* isolates placed in deionized water will form biflagellates at 42°C.
4. Pore structure of the cysts: Cysts of *N. fowleri* show only a small number of flat-edged pores, while *N. gruberi* cysts show many crater-like pores.

RESULTS

Cultivation of *N. fowleri* was considerably better on NNE medium than in the modified Nelson's medium. Growth occurred rather slowly in the latter with sufficient numbers of amoebae being available for transfer only after several weeks of incubation. It was observed, however, that cysts remained viable in this medium for months and produced normal plaques when reinoculated onto NNE.

The varied environmental conditions of the lakes with respect to the differences in age, size, sediment and public use (Table 1) provided a good cross section of thermally non-polluted lakes in Arkansas. The sampling sites generally were protected from disturbance from wind or wave action; however, some sites were located in midchannel or in public swimming areas. Samples taken from each of the seven lakes produced plaques of *Naegleria*-type organisms on NNE at 45°C (Table 2).

Many of the amoebae exhibited typical *Naegleria spp.* movement. Of the amoebae producing eruptive, finger-like pseudopodia, several were observed to have a spherical nucleolus surrounded by a clear zone and a lack of chromatin granules. These amoebae also transformed to a biflagellate stage when incubated at 42°C in deionized water. Pore structure of the cysts was of two types, those typical of *N. gruberi* and those typical of *N. fowleri*. Incubation at 48°C killed all except two cultures, P3 and P6, both isolated from Lake Poinsett. Subsequent examination indicated that culture P6 was now comprised of organisms fully consistent with *N. fowleri*, including typical cyst pore structure; while P3 still produced some cysts characteristic of *N. gruberi*. None of the isolates were pathogenic to mice when administered intranasally. Amoebae injected intracranially were found living in the brain tissue of the mice which died three days after inoculation.

Table 1. Criteria for the selection of lakes.

Lake (County)	Age (yrs)	Maximum distance length (m)	width (m)	Sediment	Public use
Poinsett (Poinsett)	35	2,414	1,609	Aufwuchs overlying organic mud debris	Fishing
Mallard (Mississippi)	14	2,407	792	Clay mud	Fishing
Big (Mississippi)	108	19,747	2,416	Organic mud debris	Fishing
Hogue (Poinsett)	11	853	836	Mud	Fishing/ hunting
Charles (Lawrence)	16	4,827	1,609	Sand/mud	Fishing/ swimming
Frierson (Greene)	5	2,835	806	Mud	Fishing/ hunting
Craighead (Craighead)	5	1,926	1,628	Gravel	Fishing/ swimming/ water skiing

Table 2. Isolation of amoebae at 45°C.

Sample site and number	Depth (m)	Temperature (C)	pH	Plaque formers
Lake Poinsett 9-19-1979				
1	0.91	27.5	5.17	+
2	0.61	26.5	5.25	+
3	0.91	27.0	5.40	+
4	1.82	24.0	5.13	+
5	0.30	27.0	5.26	-
6	0.61	27.0	5.33	+
7	0.91	26.0	5.42	-
8	0.30	26.5	5.41	+
9	0.76	27.0	4.73	-
10	0.30	27.0	5.51	+
11	4.87	22.0	5.11	-
Mallard Lake 9-22-1979				
1	0.30	18.5	5.87	+
2	1.82	20.0	6.16	+
3	0.61	20.0	6.44	-
4	0.30	20.0	6.47	-
5	2.74	20.0	6.26	+
6	0.30	19.0	6.75	-
Big Lake 9-22-1979				
1	0.30	20.0	6.71	-
2	0.91	20.0	6.63	+
3	0.30	21.0	6.79	+
4	0.30	20.0	6.79	+
5	2.74	20.0	5.88	-
6	1.82	20.0	6.35	-
7	0.61	21.0	6.40	-
Lake Hogue 9-22-1979				
1	0.15	24.0	6.25	-
2	4.57	21.0	5.90	-
3	0.91	21.0	6.25	+
4	0.61	23.0	6.40	-
5	0.76	22.0	6.50	-
6	0.91	22.0	6.20	+
7	0.61	22.0	6.50	+
Lake Charles 9-25-1979				
1	0.76	24.5	6.90	-
2	0.91	24.0	6.60	-
3	0.61	25.5	6.55	+
4	1.82	22.0	6.65	+
5	4.57	20.5	6.76	-
6	0.76	21.5	6.80	+
7	0.76	20.0	6.60	+
8	0.76	24.5	6.37	+
9	3.04	24.0	6.43	+
Lake Frierson 10-2-1979				
1	0.30	25.0	6.50	-
2	0.91	27.0	6.65	+
3	1.21	27.0	6.30	-
4	0.61	28.0	6.49	+
5	0.61	24.0	6.35	+
6	5.18	19.0	6.60	-
Craighead Lake 10-2-1979				
1	0.61	23.0	6.40	-
2	0.30	25.0	6.20	-
3	0.30	24.0	6.50	+

DISCUSSION

The poor growth in modified Nelson's medium suggests that some vital nutritional requirement is not present in the substituted liver concentrate or rabbit serum. The requirement is probably not a carbohydrate, as work by Weik and John (1977) revealed that other substrates are preferred as carbon and energy sources. This deficiency might be a protein, a vitamin or a mineral which is not available in a readily accessible form. Considering the variety of proteins that are present in the serum of any mammal, it seems unlikely that the missing substance is protein.

Earlier work in western Arkansas indicated that *N. fowleri* was not present (Bone and Becker, 1975). Sampling techniques and culture methods may provide the explanation for differing results. Cerva (1978) studied the distribution of *N. fowleri* from industrial effluent and found that all cultivation attempts from water samples were negative. However, he stated that positive cultures were collected from biological material scraped from the walls of the channel and from bottom sediment. In conditions where a small or moderate population of amoebae exists, it is likely that they are more difficult to isolate by sampling only water. Considering the cultural fastidiousness of *N. fowleri*, it is also possible that the BST agar with *Pseudomonas aeruginosa* used by Bone and Becker (1975) may not have supported adequate growth of the organisms to permit isolation. The NNE medium described by De Jonckheere et al. (1975) promotes rapid, luxuriant growth of *N. fowleri* and has been used in other recent studies (De Jonckheere and De Voorde, 1977b; Wellings et al., 1977).

The possibility that pathogenic amoebae exist in water which only seasonally reaches favorable temperatures is clearly indicated by the present investigation. De Jonckheere (1977) found that pathogenic *N. fowleri* are almost invariably associated with nonpathogenic variants. Although none of the isolates in the present study were proven to be pathogenic, the presence of nonpathogens demonstrates that environmental conditions suitable for *N. fowleri* occur in northeast Arkansas, and pathogens may also be present. It has been suggested that nonpathogenic *N. fowleri* might be considered as indicator organisms for environments where primary amoebic meningoencephalitis may be contracted (De Jonckheere et al., 1977).

Wellings et al. (1977) found that pathogenic and nonpathogenic strains show slight antigenic differences when compared by indirect immunofluorescence. Many of the amoebae isolated in this study met some of the basic criteria used for identification of *N. fowleri;* however, the IFA technique was not utilized, and an antigenic comparison between local isolates and reference strains was not made.

The present investigation indicates that *N. fowleri* exists in some northeast Arkansas lakes. Since pathogenicity was not demonstrated, future studies should include other parameters such as antigenic differences by the use of IFA in addition to mouse pathogenicity. No definite relationship was observed between the isolation of the organisms and the pH, temperature, depth, sediment type, size or public use of the lakes.

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CONNECTIONS OF THE MESENCEPHALIC LOCOMOTOR REGION (MLR) IN THE CAT[1]

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ABSTRACT

The cat entopeduncular nucleus (EN), which is the main output of the basal ganglia, is known to project to the mesencephalic tegmentum. We have been able to elicit antidromic responses in single EN neurons from the region of the mesencephalic locomotor region (MLR), then transect (precollicular-postmamillary) the brainstem and elicit rhythmic movements of the limbs by stimulation of the *same* site in the *same* animal. Injections of the fluorescent dye 2,4 diamidino phenylindole 2 HCL (DAPI) into this area induces retrograde labeling of cell bodies in EN and motor cortex. Injections of a tritiated amino acid (leucine) into the motor cortex induce terminal labeling in the area of the MLR. These studies describe convergent projections from EN and motor cortex to the MLR. These connections may be involved in the sequencing and ordering of voluntary movements in which locomotion is necessary.

INTRODUCTION

The internal segment of the globus pallidus in the monkey sends fibers to an area of the caudal mesencephalic tegmentum called the nucleus tegmenti pedunculopontinus (NTPP) (Nauta and Mehler, 1966). This area also is known to receive projections from the precentral cortex in the monkey (Kuypers and Lawrence, 1967). Two electrophysiological studies in the cat reported that entopeduncular (EN) neurons, the homologue of the primate internal pallidum, responded antidromically to electrical stimulation of NTPP. One of these (Filion and Harnois, 1978) reported that 50% of all EN neurons could be driven antidromically from a point along the pallidotegmental pathway (approximately point 1 in Fig. 1). The other study (Larsen and Sutin, 1978) reported that only 8% of EN neurons could be activated antidromically from NTPP (approximately point 2 in Fig. 1).

Physiological studies have established that an animal with a precollicular, premamillary transection (as in line A, Fig. 1) can exhibit spontaneous walking or, at least, locomotion on a treadmill (Orlovsky, 1972). With a precollicular, postmamillary transection (as in line B, Fig. 1), no spontaneous locomotion is seen but must be induced by stimulation of the MLR, a physiologically defined region which includes the cuneiform nucleus (CF) (point 3, Fig. 1) (Mori et al., 1977). With a posterior transection (such as in line C, Fig. 1), no locomotion can be induced (Grillner and Shik, 1973).

The present study was undertaken to determine if EN neurons could be antidromically activated from the same point which, when stimulated following transection (B), would induce locomotion on a treadmill. Some of these results previously have been reported (Skinner et al., 1979). Anatomical studies were also undertaken to confirm our electrophysiological results, and to determine the extent of projections to CF from the motor cortex in the cat.

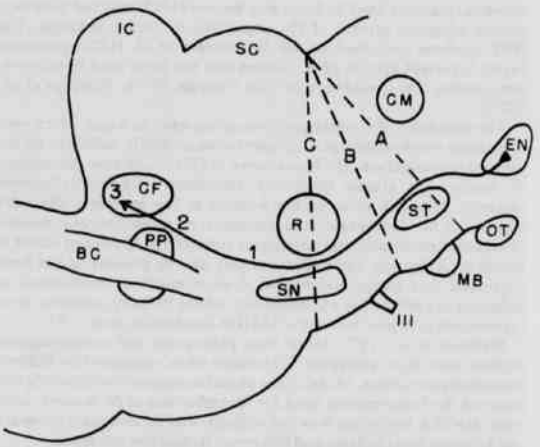

Figure 1. Diagram of part of the cat brainstem. See text for explanation of points 1, 2, 3 and lines A, B and C. BC - brachium conjunctivum, CF - cuneiform nucleus, CM - centre-median nucleus, EN - entopeduncular nucleus, IC - inferior colliculus, MB - mamillary body, OT - optic tract, PP - nucleus tegmenti pedunculopontinus, R - red nucleus, SC - superior colliculus, SN - substantia nigra, ST - subthalamic nucleus, III - oculomotor nerve.

METHODS AND MATERIALS

Fifteen adult cats were anesthetized intravenously with sodium methohexital, a short-acting barbiturate. A four-pronged stimulating comb was placed in the region of MLR, and a glass micropipette introduced into the ipsilateral EN. Subsequent procedures were carried out under locally anesthetized, paralyzed conditions. Artificial respiration was used. Single neurons in EN were isolated extracellularly and their responses to MLR stimulation recorded. Once a single EN neuron was found to respond antidromically to MLR stimulation, the recording site was marked. A precollicular, postmamillary transection was performed and the animal's weight supported by a hammock. Following recovery from paralysis and with stimulating electrodes in place, the limbs were lowered onto a moving treadmill. Stimulation of the MLR was then applied to induce locomotion.

In six other cats, the extent of afferent projections to CF and surrounding area were determined by retrograde neuronal labeling. Under barbiturate anesthesia, injections of 0.1 μl of a 2.5% solution of 4-6-diamidino-2-phenylindole 2 HCl (DAPI) in saline were made into the CF. After four days, the cats were sacrificed, perfused with 10% phosphate-buffered formalin, and the brains placed in cacodylate buffer (pH 7.2) containing 30% sucrose. Sections of 30 μm were mounted from distilled water and air dried without coverslipping. Observation was made with a fluorescence microscope using excitation filters at 360 nm wavelength and observation filters at 430 nm. Labeled neurons containing DAPI fluoresced blue.

[1]Supported by USPHS Grants RR-0530, MH-32878 and NS-15359

In another series of four cats, motor cortex projections to CF were determined by autoradiography. ^{3}H-leucine was injected (1 μl [50 μCi/μl]) into the axial representation of the motor cortex or into the distal forelimb representation. After four days, the animals were sacrificed and perfused with 10% buffered formalin. Frozen sections of 20 μm were dipped in NTB-2 emulsion and, after six weeks, the sections were developed and stained with hematoxylin and eosin.

RESULTS

Antidromic responses in EN were elicited by electrical stimulation of medial sites within CF, while orthodromic responses could be elicited from more lateral locations in the mesencephalon. The best point for inducing locomotion or rhythmic limb movement in these animals was also invariably located in medial CF. EN neurons activated antidromically (n=7) followed 300-500 Hz stimuli in trains of up to four shocks at a latency of 2.2±0.6 ms (mean and standard deviation). In anterior EN, where most responses were obtained, EN neurons activated antidromically represented 6% of the 119 neurons studied.

In our anatomical studies using retrograde neuronal transport of DAPI, labeled neurons were observed, in descending order of number, in the ventral tegmental area, medial substantia nigra (pars compacta), sub- and hypothalamus, precruciate (motor) cortex, ansa lenticularis and EN. Even though very few labeled EN neurons were observed, their distribution closely matched that of the antidromically identified neurons discussed above.

In our anatomical studies using anterograde transport of a tritiated amino acid, autoradiographic silver grains were found in the ipsilateral CF only in cats injected in the axial representation of the motor cortex. No labeling was observed following injections into the distal forelimb representation. Labeling observed in CF was diffuse, but distinct. These studies indicate that medial motor cortex and pallidal efferents project to the CF.

DISCUSSION

These preliminary studies indicate that a small portion of the pallidotegmental projection descends as far as the CF and appears to terminate within the MLR. From reports in the literature, the CF, at least the dorsal part of NTPP, and perhaps portions of the locus coeruleus all form part of the MLR (Mori et al., 1977). There appears to be a convergence of cortical (Kuypers and Lawrence, 1967), pallidal (Nauta and Mehler, 1966; Skinner et al., 1979) and nigral (Skinner et al., 1979) inputs at this level. Our anatomical studies support this notion.

The functional significance of these pathways remains to be discovered. However observations noted during these experiments provided some indications. When larger currents or higher frequencies than those mentioned were applied to the MLR, considerable extensor rigidity was observed instead of rhythmic alternating movements. This suggests that "overdriving" of the MLR by cortical, pallidal and/or nigral afferents may be involved in certain pathological cases of rigidity. By the same token, lack of input to this region may be responsible for the inability to *initiate* locomotion, such as that observed in Parkinson's disease. We subscribe to the notion that motor cortex and basal ganglia interactions with the MLR may be involved in the "triggering" of locomotion generators, a process either attenuated or exacerbated in diseased states. The basal ganglia have been implicated in the sequencing and ordering of movements (Garcia-Rill et al., 1979). The link between the EN and MLR may subserve the function of initiating sequences of movements in which locomotion is necessary.

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A PRELIMINARY INVESTIGATION OF THE GROUND-WATER RESOURCES OF NORTHERN SEARCY COUNTY, ARKANSAS

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ABSTRACT

Two aquifers are extensively used by residents of small communities and rural areas in northern Searcy County, Arkansas. The Mississippian Boone-St. Joe aquifer is generally the less productive and the shallower of the two. Ground-water yields for the Boone-St. Joe range from 0.5 to 75 gpm with a median yield of 5 and a mean of 9.8 gpm. Well depths range from 100 to 754 feet with a median depth of 350 feet and a mean of 360 feet. Confined conditions are indicated by the greater depths, whereas the Boone-St. Joe aquifer is unconfined when exposed at the surface.

Underlying the Boone-St. Joe aquifer is an aquifer zone composed of sands, sandy limestones, and/or dolomitic limestones below the Chattanooga Shale and above and including the Everton Formation. This aquifer can be composed of one or more of the following units: upper Everton, St. Peter, Clifty, Sylamore, Lafferty, St. Clair and/or Plattin. The range in yields for this aquifer is 1 to 80 gpm with a median yield of 9 and a mean of 17 gpm. Well depths range from 200 to 875 feet with a median and mean depth of 570 feet.

A statistical correlation was found among well yields (gpm), regolith thickness, depth of well, and cave intersection by the well. The results indicate that greater yields can be obtained in areas of thicker regolith. Cave presence was also found to enhance yields. A strong relationship between cave presence and deeper regolith was observed. These three relationships demonstrate increased weathering, and thus water flow along fractures. The effect of joints closing off at depth produced a strong relationship between shallower wells and greater yields within the Boone-St. Joe aquifer.

INTRODUCTION

Ground water is the most important source of domestic-use water in rural areas and communities in northern Searcy County, Arkansas, but little is known about its occurrence and movement. Few detailed hydrogeologic reports have been written about Searcy County, although numerous studies have been made concerning formations dealt with in this report in other areas of the state. Isopachous and structural contour maps of some of the formations discussed in this report were made by Caplan (1957).

The purposes of this study are: (1) identification of aquifers, (2) determination of range of depths and yields of wells, (3) determination of direction(s) of ground-water movement from a piezometric surface map, and (4) investigation of statistical inter-relationships among depth of well, depth to water, yield, regolith thickness, and cave presence in a well to determine geologic controls.

LOCATION AND GEOLOGY

The study area has been confined to northern Searcy County, specifically north of township 14 and bounded east and west by Range 14 West and 18 West, respectively (Fig. 1). The southern boundary is marked by the Boston Mountain Escarpement. This area was selected to facilitate the general study of aquifers of the Springfield Plateau.

Mississippian, Devonian, Silurian and Ordovician rocks are exposed at the surface of northern Searcy County. The generalized stratigraphy of the study area is shown in Figure 2, although thinner and less common units are not represented. Unconformities are common in the sequence sometimes making it difficult to determine the exact formations present in a well.

The Boone Formation crops out through most of the study area. However, dissection by major stream systems has exposed Devonian, Silurian and Ordovician rocks locally. The rocks of the area dip

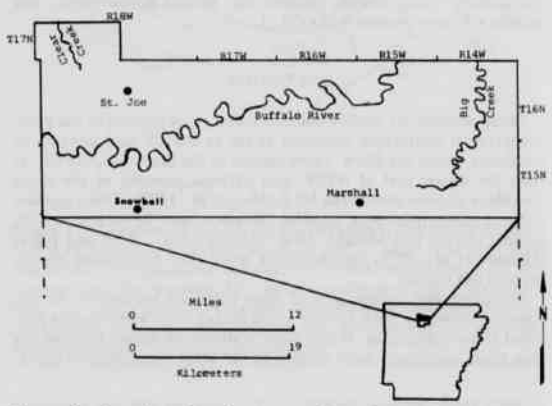

Figure 1. Location of study area, northern Searcy County, Arkansas.

gently on the southwestern flank of the Ozark Dome, with little deformation. A few normal faults are present, but they are believed to have only localized effect on the hydrogeology of the area. There is extensive karst developed in the carbonate rocks, specifically in the Boone and St. Joe limestones. Caves, springs, dolines and losing streams are common geomorphic features. Joints have been enlarged by solution, thus enhancing the porosity and permeability.

METHODS AND MATERIALS

Records of Searcy County water wells were obtained from the Arkansas Geologic Commission. It was possible from these to accurate-

SYSTEM	STAGE	FORMATION	THICKNESS (in ft.)	GENERAL ROCK TYPE
MISSISSIPPIAN	CHESTER	Pitkin	230-250	Limestone
		Fayetteville		
		Upper Member	30-55	Black shale
		Wedington Member	20-40	Sandstone
		Lower Member	260-280	Black shale
		Batesville	62-76	Sandstone
		Hindsville	0-12	Limestone
	MERAMEC	Ruddell	120-272	Shale
		Moorefield	25-199	Shale
	OSAGE	Boone	100-400	Cherty limestone
		St. Joe	0-100	Limestone
	KINDERHOOK	Bachelor	1-4	Green shale
		Chattanooga	0-38	Black shale
		Sylamore	2-5	Sandstone
DEVONIAN	MIDDLE DEVONIAN	Clifty	0-3	Sandy limestone
		Penters	0-91	Chert
SILURIAN	NIAGARAN	Lafferty	0-85	Limestone
		St. Clair	0-100	Limestone
	LOWER SIL.	Brassfield	0-26	Limestone
ORDOVICIAN	CINCINNATIAN	Cason	0-23	Shale
		Fernvale	0-125	Limestone
	MIDDLE ORDOVICIAN	Kimmswick	0-60	Limestone
		Plattin	0-240	Limestone
	LOWER ORDOVICIAN	Joachim	0-150	Dolomite
		St. Peter	0-175	Sandstone
		Everton	0-600	Dolomitic sandstone
		Black Rock	0-55	Dolomitic limestone
		Smithville	0-65	Limestone
		Powell	0-200	Dolomite
		Cotter	500+	Dolomite
		Jefferson City	300-400	Dolomite
		Roubidoux	135-190	Oolitic limestone
		Gasconade	100-200	Limestone

Figure 2. Generalized stratigraphy of northwest Arkansas (after Caplan, 1954).

ly locate 72 wells with the aid of driller directions, a county platt book, and topographic maps. From the gross lithologic log reported on each record, it was possible to determine the aquifer(s) that supplied water to each well. The occasional absence of formations due to unconformities and poor lithologic descriptions did not significantly hamper aquifer determination, as the aquifers are usually composed of more than one geologic formation that can be distinguished by marker horizons. Other information provided by the well records include: (1) depth to water, (2) driller's estimate of yield in gallons per minutes (gpm), (3) depth to bedrock, and (4) the presence of caves and their depth below land surface. With the aid of topographic maps, elevations of the well tops were determined with subsequent plotting of the static level control points of the piezometric surface map. The Spearman-Rank Correlation Coefficient test (Siegel, 1956) was then used to make preliminary tests among the following parameters: (1) well yield, (2) regolith thickness (depth to bedrock), (3) cave presence, and (4) total depth of well.

RESULTS

Two important aquifer zones were found to be extensively utilized by residents throughout northern Searcy County. The more shallow and extensively used aquifer is the Mississippian Boone-St. Joe limestone. This aquifer is generally the less productive of the two with a range in yield of 0.5 to 75 gpm but with a median and mean productivity of only 5 and 9.8 gpm, respectively (Table 1).

Table 1. Aquifer depth and yield ranges.

Aquifer	Depth (ft.) Range	Median	Mean	Yield (gpm) Range	Median	Mean
Boone - St. Joe	100-754	350	360	0.5-75	5.0	9.8
Sylamore - Everton	200-875	570	570	1.0-80	9.0	17

Total well depths drilled in the Boone-St. Joe aquifer range from 100 to 754 feet with a median and mean depth of 350 and 360 feet, respectively. While most of these depths represent wells in which drilling began in the Boone, the deepest wells represent drilling which began in upper Mississippian and Pennsylvanian rocks. Wells that penetrated the entire thickness of the Boone-St. Joe indicate that this aquifer achieves a maximum thickness of 423 feet in the southern part of the study area. The Boone-St. Joe aquifer is unconfined where exposed at the surface, but is confined where it is covered by younger strata.

A piezometric surface map for the Boone-St. Joe was prepared, which displays several hydrologic features (Fig. 3). The aquifer discharges along portions of the Buffalo River, Big Creek, and Clear Creek. The piezometric surfaces slope in a general southeastern direction with some northwesterly movement from drainage divides. The average hydraulic gradient of 75 feet per mile indicates rapid movement and drainage. A ground-water drainage divide is observed between the Buffalo River and Big Creek. Another drainage divide is observed northwest of St. Joe. A possible cone of depression appears to be developing in the town of Snowball where the aquifer is heavily utilized locally.

The next important aquifer zone is a group of sandstones, limestones, and dolomites below the Chattanooga Shale (where present) or below the St. Joe where the Chattanooga is missing. This aquifer zone generally consists of one or more of the following units: Sylamore Sandstone (upper Devonian), Clifty Limestone (Devonian), Lafferty Limestone (Silurian), St. Clair Limestone (Silurian), Plattin Limestone (middle Ordovician), St. Peter Sandstone (middle Ordovician), and/or Everton Formation (lower Ordovician). In this area, the units above the St. Peter are generally thin, unconformable and are undifferentiable from drillers' poor lithologic descriptions. The upper Everton is the most important formation within this aquifer zone, but the overlying units commonly contribute water to

the wells. This aquifer zone has been termed collectively as the Evermore by Ogden et al. (1980).

This aquifer zone is considered a separate and distinct aquifer from the Boone-St. Joe, due to the presence of the Chattanooga Shale which acts as an aquiclude between the two aquifer zones. It confines the aquifer zone below it except where stream incision has exposed pre-Mississippian units. There is a distinct difference in head levels in neighboring wells utilizing the different aquifers. However, there is considerable hydrologic interaction among the different formations comprising the Sylamore-Everton which warrants their consideration as a single aquifer.

The range of yield for the Sylamore-Everton aquifer zone is 1 to 80 gpm with a median and mean range of 9 and 17 gpm, respectively. Well depths range from 200 to 875 feet with a median and mean depth of 570 feet (Table 1). These well depths commonly penetrated some of the Boone-St. Joe, as most drilling was initiated on the Springfield Plateau which is formed by the Boone Formation. No wells examined were observed to penetrate the entire thickness of the Everton. Often, yields in this aquifer zone reflect some contribution of water from the Boone-St. Joe through fractures in the Chattanooga, but this contribution is considered negligible as drilling would have ceased before the Sylamore-Everton was penetrated.

A piezometric surface map was not prepared for this aquifer zone as the authors feel that data obtained in this study was insufficient to do so. However, a map of static water levels and well locations has been prepared (Fig. 4). This shows, however, an erratic occurrence of head levels which is due to the productive potential and occurrence, or lack thereof, of the interacting units above the Everton. A vague easterly trend of movement is indicated by the map and is supported by observations of the authors of the Sylamore-Everton in Marion County (due north of the study area) where plotted well density is greater. Ground-water movement there is toward the east where discharge occurs along portions of the White River.

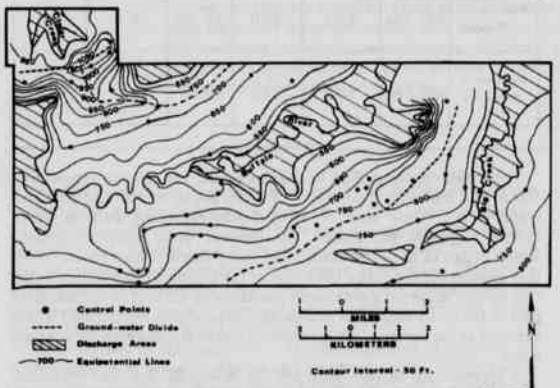

Figure 3. Piezometric surface map of the St. Joe-Boone Aquifer Zone.

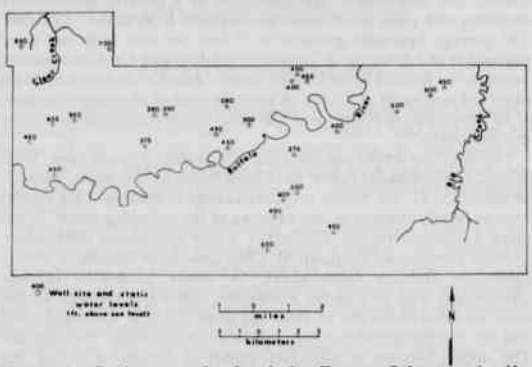

Figure 4. Static water levels of the Everton-Sylamore Aquifer Zone.

STATISTICAL RELATIONSHIPS

The relationships among yield, regolith thickness, depth of well and the presence of caves were determined from the hydrologic data found on the well driller reports to determine some of the geologic controls on well yield. The Spearman-Rank Correlation Coefficient test was used for the comparisons with the aid of computer SAS procedures (Barr et al., 1976).

The first relationship tested was between well water yield, as estimated by drillers, and regolith thickness. Regolith thicknesses on the Boone-St. Joe aquifer ranged from 3 to 121 feet with a median and mean of 17 and 27 feet, respectively. Thicknesses of regolith for wells in the Sylamore-Everton aquifer zone range from 4 to 100 feet with a median and mean of 20 and 25 feet, respectively, but usually these regolith values reflect weathering of the Boone and St. Joe limestones. The data of each aquifer were correlated both individually and collectively and the same resultant alpha significance level in both cases was obtained. The results show a linear relationship at an alpha = .001 probability level, indicating that higher well yields are obtained when wells are drilled in areas of thick regolith. In carbonate rocks, weathering is deeper along fractures, creating an irregular regolith-bedrock contact known as pinnacles and cutters (Sweeting, 1973). Fracture enlargement by solution as well as joint expansion by unloading of overburden creates a zone of increased permeability through which ground water can move more readily, thus yielding greater quantities of water to the well (Fig. 5). Therefore, the thicker regolith areas accurately indicate zones of fracture enlargement. Lattman and Parizek (1964) have found greater yields along photo-lineaments that are believed to represent fracture zones. It is possible that, by delineating zones of greater regolith thickness, greater yielding wells can be located. Ogden et al. (1980) found a similar relationship in northwest Arkansas.

It was also found that in the Boone-St. Joe aquifer, shallower wells have greater yields (alpha = .04). This is due to closing off of fractures at depth since the influence of weathering and unloading decreases with depth (Davis and DeWeist, 1967).

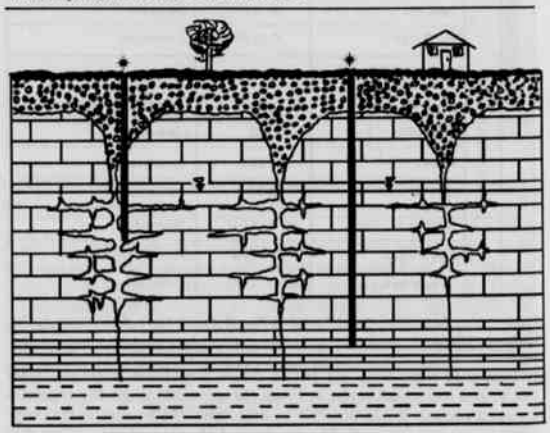

Figure 5. Diagrammatic representation of the relationship of pinnacles and cutters to fracture zones and regolith thickness.

A relationship was found between greater yields and cave presence in a well. This relationship was not due to water-filled cavities as the water table was generally below the level of the intersected cave. Caves commonly are oriented along joints and fractures (Barlow and Ogden, 1978). Therefore, wells intersecting caves are also likely to be intersecting these zones of weakness along which water can more easily migrate. Lattman and Parizek (1976) also found that more caves are intersected by wells drilled on fractures. This hypothesis is supported by the observation that thicker regolith was also found to be an indicator of cave presence in the subsurface. All wells that penetrated caves in northern Searcy County were drilled on thicker regolith (generally greater than 15 ft.). However, the number of wells drilled on thicker regolith that did not penetrate caves outnumber those that did three to one. Therefore, deeper regolith is considered to be merely one indicator and not proof of cave presence in the subsurface.

CONCLUSION

Two important aquifers representing combinations of pre-Pennsylvanian geologic formations are found to be utilized extensively by residents and communities in northern Searcy County. The Boone-St. Joe limestone aquifer is shallower, but less productive, than the Sylamore-Everton sandstone aquifer zone. More wells obtain water from the Boone-St. Joe aquifer, but when greater production is needed, the deeper Sylamore-upper Everton aquifer zone is utilized. This deeper aquifer is more commonly used by communities and the poultry industry.

Statistical correlations show that greater yields can be obtained where thicker regolith exists as concluded by Ogden et al. (1980). Thicker regolith zones are believed to represent zones of fractures enlarged by solution and along which water can be more easily transmitted. Caves are more often intersected by wells drilled in areas of thicker regolith, and wells intersecting caves have greater yields. This further substantiates the hypothesis of there being thicker regolith along fractures, since caves form by the solution of limestone along such zones of weakness.

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RECENT MOLLUSCA OF ARKANSAS WITH ANNOTATIONS TO SYSTEMATICS AND ZOOGEOGRAPHY

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ABSTRACT

A total of 223 taxa of Mollusca are presently known from Arkansas. The geological history and geomorphology of the region, particularly the presence of the Interior Highlands, have been responsible for the development of a diverse molluscan fauna. Thirty regionally endemic forms are included among the 107 terrestrial gastropods, 36 aquatic gastropods, 65 unionacean mussels, and 15 sphaeriacean clams.

INTRODUCTION

The first survey of Arkansas Mollusca was Sampson's (1893, 1894) report of the Gastropoda and Sphaeriidae. The Unionidae were cataloged by Call (1895). Since these initial reports, there have been few comprehensive publications concerning Arkansas mollusks. During the interim, limited species surveys, several species descriptions, and various miscellaneous studies have appeared periodically (e.g. Ortmann and Walker, 1912; Wheeler, 1914, 1918; Rehder, 1932; Kraemer, 1970; Gordon et al. 1980a). Recently, Hubricht (1972) published a fairly comprehensive list (89 taxa) of terrestrial gastropods and Gordon et al. (1980b) presented a historical review and consideration of the regional distribution patterns of the Unionacea with respect to Arkansas.

METHODS AND RESULTS

The molluscan fauna of Arkansas has been investigated by personal collecting and examination of major museum collections (see Gordon et al. 1980a, b). This has been augmented by published records which are either based on museum reference collections or may be collaborated by more than one published account. Nomenclature follows Burch (1962) and Hubricht (1972) for the terrestrial Gastropoda; Baker (1911), Goodrich (1939), Clench (1962), Clench and Fuller (1965), Clarke (1973), and Thompson *(pers. comm.)* for aquatic Gastropoda; Ortmann and Walker (1922), Clarke (1973), and Gordon et al. (1980b) for the Unionacea; and Herrington (1962) and Burch (1975) for the Sphaeriacea.

A total of 223 taxa of Mollusca are presently known from Arkansas. This represents 107 terrestrial Gastropoda (Table 1), 36 aquatic Gastropoda (Table 2), and 80 Bivalvia (Table 3). The bivalves include 65 unionacean mussels and 15 sphaeriacean clams, five of which are listed provisionally. Fifteen terrestrial gastropods, seven aquatic gastropods, and eight unionaceans are endemic within the Interior Highlands. No endemic sphaeriaceans are known. Some annotations are necessary for several species. These are as follows:

1. Subspecific nomenclature represents geographic subspecies and not ecophenotypic variation.
2. Current research and revision of the Succineidae will probably result in a reduction of species through synonymy (Wu, *pers. comm.*).
3. *Somatogyrus wheeleri* and *S. amnicoloides* appear to be known only by the type specimens. These species were collected together at the same locality. Further study may show them to be conspecific. The type locality is now receiving hypolimnetic release from DeGray Reservoir.
4. Four ecophenotypes of *Goniobasis potosiensis* have been described as subspecies. The forms known as *plebeius* Anthony, the typical form, and *crandalli* Pilsbry, a stunted form with rounded whorls from Mammouth Springs, Fulton County, occur in Arkansas.
5. The taxonomy of *Anculosa arkansensis* is unclear. Goodrich (1939) stated that its general appearance was close to *Nitocris trilineata*. The shell of specimens I collected from tributaries of the North Fork of the White River are similar to *Nitrocris*. Anatomical examination will be necessary before the generic position of this species can be confirmed. If a *Nitocris* species, this may represent a relict population of a previously described species.
6. Te (1975) has concluded that *Physa anatina* Lea is a form of *P. virgata*.
7. Clarke (1973) has concluded that *Fusconaia undata* (Barnes) is more than likely the large river ecophenotype of *F. flava*.
8. *Pleurobema cordatum* includes a complex group of ecophenotypes that have generally been given subspecific status. These include, by increasing inflatedness of the shell, *coccineum* Conrad (also known as *missouriensis* Marsh), *catillus* Conrad, *plenum* Lea, and *pyramidatum* Lea (Ortmann, 1919).
9. *Anodonta grandis* is a substantially variable species with several ecophenotypes. Synonymized here is the slough form *corpulenta* Cooper.
10. Strophitini is proposed as a new tribe within the unionid subfamily Anodontinae. The basis for this division is the digenae arrangement of the marsupium in the outer gill. Ortmann (1912) considered this to be the most advanced gill form in the Anodontinae. *Strophitus*, previously classified in the Anodontini (Clarke, 1973), is the only genus in the Unionacea that has this form of gill. Ortmann (1912) noted some similarities in the anatomy (primarily pigmentation) and the shell (beak sculpture and other undefined characters) to the *Alasmidonta*. The shell is not necessarily a good phylogenetic character (Heard and Guckert, 1970); however, the general outline of *Stophitus* often resembles that of the Alasmidontini. Vestigial swellings in the area of the pseudocardinals suggest an association with the Alasmidontini in which the pseudocardinals are single in both valves and the interdentum of the left valve is reflected into a tooth-like structure. These dental characters appear to hold true throughout the Alasmidontini. In *Strophitus*, the vestigial swellings correspond to the position of the single pseudocardinals and the reflected interdentum. The tribe is monogeneric — *Strophitus*.
11. *Actinonaias carinata* includes a form known as *gibba* Simpson. This is probably an ecophenotypic variation.
12. The shell of *Actinonaias ellipsiformis pleasii* is distinct from *A. e. ellipsiformis*. It is geographically restricted to the White River system of the Ozark Plateaus in which *A. e. ellipsiformis* is not distributed. *Actinonaias ellipsiformis pleasii* appears to be a true subspecies, if not a separate species.

13. *Lampsilis reeveiana* (Lea) is recognizable from its type description and lithograph. The holotype is extant in the U.S. National Museum of Natural History (USNMNH 8505). Previous difficulty in identifying this endemic Ozark Plateaus species has been partially due to Lea's (1852) mispublication of the type locality: Alexandria, Louisiana. This should be White River, Arkansas. *Reeveiana* has 35 years priority to Call's (1887) *brevicula*.

14. Most of the specimens of *Lampsilis ovata* found in Arkansas are the form known as *ventricosa* Barnes; although, some specimens are occasionally referred to as *satura* Lea. *Ventricosa* is the small river ecophenotype (Ortmann, 1919; van der Schalie, 1938). The relationship of *satura* is not presently known, it may be a southern cline of *ventricosa*. Clarke (1973) applies *ventricosa* only at an infrasubspecific level.

15. The taxonomy of *Lampsilis orbiculata* and *L. higginsii* is unclear. They are quite similar in appearance and have variously been considered separate species, subspecies, and the same species (Simpson, 1914; Ball, 1922; Baker, 1928; van der Schalie and van der Schalie, 1950; Parmalee, 1967). *Lampsilis higginsii* is the Mississippi River counterpart of *L. orbiculata* of the Ohio River system. Simpson (1914) identified a subspecies of *L. higginsii* that he considered intermediate between the two "species." Buchanan and Oesch *(pers. comms.)* recently have collected both forms from rivers in Missouri that flow into Arkansas (Little Black and St. Francis rivers). The presence of both forms in southern Missouri and Arkansas is quite possible when the former channels of the Mississippi and Ohio rivers are examined (see Gordon et al. 1980b). For the present, the two forms are listed as separate species.

Table 1. Arkansas Terrestrial Gastropoda.

Subclass Prosobranchia Edwards
Order Archaeogastropoda Thiele
Family Helicinidae Ferussac
Helicina (Oligyra) orbiculata (Say)
Subclass Pulmonata Cuvier
Order Basommatophora Keferstein
Family Carychiidae Jeffreys
Carychium exiguum (Say)
Order Stylommatophora Schmidt
Suborder Orthurethra Pilsbry
Family Cionellidae Koblet
Cionella lubrica (Muller)
Family Valloniidae Morse
Vallonia perspectiva Sterki
Family Pupillidae Turton
Subfamily Pupillinae Pilsbry
Pupoides albilabris (Adams)
Subfamily Gastrocoptinae Pilsbry
Gastrocopta (Gastrocopta) pellucida hordencella (Pilsbry)
G. (G.) procera (Gould)
G. (G.) rupicola (Say)
G. (Albinula) armifera (Say)
G. (A.) contracta (Say)
G. (A.) holzingeri (Sterki)
G. (Vertigopsis) tappaniana (Adams)
G. (Privatula) corticaria (Say)
Subfamily Vertigininae Thiele
Vertigo (Vertigo) ovata Say
V. (V.) rugosula Sterki
V. (V.) tridentata Wolf
V. (Angustula) milium (Gould)
V. (Vertillaria) oscariana Sterki
Family Strobilopsidae Jooss
Strobilops (Strobilops) aenea Pilsbry
S. (S.) labyrinthica (Say)
S. (S.) texasiana (Pilsbry and Ferriss)
Suborder Heterurethra Pilsbry
Family Succineidae Beck
Succinea (Novisuccinea) ovalis Say
S. (Calcisuccinea) concordialis Gould
S. (C.) luteola Gould
S. (?) indiana Pilsbry
S. (?) witteri Shimek
Catinella avara (Say)
C. oklahomarum (Webb)
C. texana Hubricht
C. vermeta (Say)
C. wandae (Webb)
Oxyloma (Neoxyloma) salleana (Pfeiffer)
Suborder Sigmurethra Pilsbry
Family Philomycidae Keferstein
Philomycus carolinianus (Bosc)
Pallifera hemphilli marmorea Pilsbry
P. mutabilis Hubricht
P. ragsdalei (Webb)
Family Enodontidae Pilsbry
Subfamily Enodontinae Pilsbry
Anguispira alternata (Say)
A. strongylodes (Pfeiffer)
Discus patulus (Deshayes)
Subfamily Helicodiscinae Pilsbry
Helicodiscus (Helicodiscus) parallelus (Say)
H. (Hebetodiscus) singleyanus (Pilsbry)
H. (?) jacksoni Hubricht
H. (?) notius Hubricht
Subfamily Punctinae Morse
Punctum (Punctum) minutissimum (Lea)
P. (Toltecia) vitreum Baker
Family Limacidae Gray
Subfamily Limacinae Gray
Limax flavus Linnaeus
Lehmannia poirieri (Mabille)
Deroceras laeve (Muller)
Subfamily Milacinae Cockerell
Milax gagates (Draparnaud)
Family Zonitidae Pilsbry
Subfamily Zonitinae Pilsbry
Retinella (Glyphyalus) wheatleyi (Bland)
R. (G.) lewisiana (Clapp)
R. (Glyphalinia) indentata (Say)
R. (G.) luticola Hubricht
R. (G.) solida (Baker)
Mesomphix (Omphalina) capnodes (Binney)
M. (O.) cupreus (Rafinesque)
M. (O.) friabilis (Binney)
M. (?) globosus (Macmillan)
Paravitrea (Paravitrea) significans (Bland)
P. (P.) simpsoni (Pilsbry)[1]
P. (P.) aulacogyra (Pilsbry and Ferriss)[1]
P. (P.) petrophila (Bland)
P. (Paravitreops) multidentata (Binney)
Hawaiia minuscula (Binney)
Subfamily Euconulinae Baker
Euconulus chersinus (Say)
Guppya sterkii (Dall)
Subfamily Gastrodontinae Tryon
Ventridens demissus (Binney)
V. ligera (Say)
Zonitoides arboreus (Say)
Striatura (Pseudohyalina) meridionalis (Pilsbry and Ferriss)
Family Haplotrematidae Baker
Haplotrema concavum (Say)
Family Bulimulidae Pilsbry
Bulimulus (Rhabdotus) dealbatus (Say)
Family Polygyridae Pilsbry
Subfamily Polygyrinae Pilsbry
Polygyra (Daedalochila) leporina (Gould)
P. (D.) texasiana (Moricand)
P. (D.) tridontoides (Bland)
P. (D.) dorfeuilliana Lea
P. (D.) jacksoni (Bland)[1]
P. (D.) peregrina Rehder[1]
P. (?) lithica Hubricht
Stenotrema (Stenotrema) stenotrema (Pfeiffer)
S. (S.) labrosum (Bland)[1]
S. (S.) pilsbryi (Ferriss)[1]
S. (S.) blandianum (Pilsbry)[1]
S. (S.) unciferum (Pilsbry)[1]
S. (Euchemotrema) fraternum (Say)
S. (E.) leai (Binney)
Practicolella berlandieriana (Moricand)
Mesodon (Mesodon) clausus (Say)
M. (M.) thyroidus (Say)
M. (M.) zaletus (Binney)
M. (M.) elevatus (Say)
M. (M.) binneyanus (Pilsbry)[1]
M. (M.) clenchi (Rehder)[1]
M. (M.) indianorum (Pilsbry)[1]
M. (M.) kiowaensis (Simpson)[1]
M. (M.) roemeri (Pfeiffer)
M. (Patera) perigraptus Pilsbry
M. (Inflectarius) inflectus (Say)
M. (I.) magazinensis (Pilsbry and Ferriss)[1]
Subfamily Triodopsinae Pilsbry
Triodopsis (Triodopsis) cragini Call[1]
T. (T.) neglecta (Pilsbry)[1]
T. (T.) vultuosa (Gould)
T. (Xolotrema) fosteri (Baker)
T. (X.) obstricta (Say)
T. (Neohelix) albolabris (Say)
T. (N.) divesta (Gould)
T. (N.) multilineata (Say)

[1]Endemic to the Interior Highlands Region.

Table 2. Arkansas Aquatic Gastropoda.

Subclass Prosobranchia Edwards
Order Mesogastropoda Thiele
Superfamily Viviparacea
Family Viviparidae Gray
Subfamily Viviparinae Gill
Viviparus subpurpureus (Say)
V. intertextus (Say)
V. georgianus (Lea)
Subfamily Lioplacinae Gill
Lioplax suculosa (Menke)
Campeloma subsolidum (Anthony)
Superfamily Rissoacea
Family Hydrobiidae Troschel
Subfamily Hydrobiinae Troschel
Cincinnatia integra (Say)
Probythinella binneyana (Hannibal)
Pyrgulopsis ozarkensis Hinkley[1]
Subfamily Lithoglyphinae Fischer
Somatogyrus crassilabris Walker[1]
S. subglobosus (Say)
S. wheeleri Walker[2]
S. amnicoloides Walker[2]
Subfamily Amnicolinae Tryon
Amnicola cora Hubricht[1]
Family Pomatiopsidae Stimpson
Pomatiopsis lapidaria (Say)
Superfamily Cerithacea
Family Pleuroceridae Fischer
Lithasia verrucosa (Rafinesque)
Pleurocera alveare (Conrad)
P. canaliculatum (Say)
P. acuta Rafinesque
Goniobasis potosiensis Lea[3]
Anculosa arkansensis Hinkley[1]
Subclass Pulmonata Cuvier
Order Basommatophora Keferstein
Superfamily Lymnacea
Family Lymnaeidae Rafinesque
Lymnaea (Pseudosuccinea) columella (Say)
L. (Fossaria) humilis (Say)
L. (F.) obrussa (Say)
L. (Bakerilymnaea) bulimoides (Lea)
Superfamily Physacea
Family Physidae Fitzinger
Physa gyrina Say
P. virgata Say
Superfamily Planorbacea
Family Planorbidae Rafinesque
Subfamily Planorbinae Rafinesque
Tribe Planorbini
Gyraulus parvus (Say)
Tribe Helisomatini
Promenetus exacuous (Say)
Menetus (Micromenetus) dilatatus (Gould)
Helisoma (Helisoma) anceps (Menke)
H. (Piersoma) trivolvis (Say)
Family Ancylidae Rafinesque
Laevapex fuscus (Adams)
L. diaphanus (Haldeman)
Ferrissia rivularis (Say)
F. walkeri (Pilsbry and Ferriss)
F. fragilis (Tryon)

[1]Endemic Interior Highlands species restricted to the Ozark Plateaus.
[2]Endemic Interior Highlands species restricted to the Ouachita Mountains.
[3]Endemic Interior Highlands species.

Table 3. Arkansas Bivalvia.

Order Eulamellibranchia
Superfamily Unionacea
Family Margaritiferidae
Subfamily Cumberlandiinae
Cumberlandia monodonta (Say)
Family Unionidae
Subfamily Ambleminae
Tribe Amblemini
Fusconaia flava (Rafinesque)
F. ebena (Lea)
F. ozarkensis (Call)[1]
Amblema plicata (Say)
Quadrula pustulosa (Lea)
Q. nodulata (Rafinesque)
Q. quadrula (Rafinesque)
Q. metanevra (Rafinesque)
Q. cylindrica (Say)
Tritogonia verrucosa (Rafinesque)
Plectomerus dombeyanus (Valenciennes)
Tribe Megalonaiadini
Megalonaias gigantea (Barnes)
Subfamily Unioninae
Tribe Pleurobemini
Cyclonaias tuberculata (Rafinesque)
Pleurobema cordatum (Rafinesque)
Elliptio dilatatus (Rafinesque)
Uniomerus tetralasmus (Say)
Subfamily Anodontinae
Tribe Alasmidontini
Lasmigona (Pterosyna) complanata (Barnes)
L. (Lasmigona) costata (Rafinesque)
Alasmidonta (Pressodonta) calceola (Lea)
A. (Decurambis) marginata Say
Arcidens confragosus (Say)
Arkansia wheleri Ortmann and Walker[2]
Tribe Anodontini
Anodonta (Pyganodon) grandis Say
A. (Utterbackia) imbecilis Say
A. (U.) suborbiculata Say
Andontoides ferussacianus (Lea)
Simpsoniconcha ambiqua (Say)
Tribe Strophitini n. t.
Strophitus undulatus (Say)
Subfamily Lampsilinae
Tribe Ptychogenini
Pytchobranchus occidentalis (Conrad)[3]
Tribe Mesogenini
Obliquaria reflexa Rafinesque
Cyprogenia aberti (Conrad)[3]
Tribe Heterogenini
Obovaria olivaria (Rafinesque)
O. jacksoniana Frierson
Actiononaias carinata (Barnes)
A. ellipsiformis ellipsiformis (Conrad)
A. ellipsiformis pleasii (Marsh)[1]
Truncilla truncata Rafinesque
T. donaciformis (Lea)
Plagiola lineolata Rafinesque
Leptodea leptodon (Rafinesque)
L. fragilis (Rafinesque)
Proptera laevissima (Lea)
P. purpurata (Lamarck)
P. capax (Green)
Carunculina parva (Barnes)
C. texasensis (Lea)
C. glans (Lea)
Villosa arkansasensis (Lea)[3]
V. lienosa (Conrad)
V. iris (Lea)
Ligumia subrostrata (Say)
L. recta (Lamarck)
Lampsilis anodontoides (Lea)
L. radiata siliquoidea (Barnes)
L. hydiana (Lea)
L. reeveiana (Lea)[1]
L. streckeri Frierson
L. rafinesqueana Frierson[1]
L. ovata (Say)
L. orbiculata (Hildreth)
L. higginsii (Lea)
Dysnomia (Truncillopsis) triquetra (Rafinesque)
D. (Torulosa) florentina (Lea)
D. (T.) turgidula (Lea)
Superfamily Sphaeriacea
Family Corbiculidae
Corbicula cf. *fluminea* (Muller)
Family Sphaeriidae
Sphaerium striatinum (Lamarck)
Musculium lacustre (Muller)
M. partumeium (Say)
M. securis (Prime)
M. transversum (Say)
Pisidium (Cyclocalyx) casertanum (Poli)
P. (C.) compressum Prime
P. (C.) fallax Sterki
P. (C.) variabile Prime
P. (C.) adamsi Stimpson (Hinkley, 1916)
P. (C.) nitidum Jenyns (Burch, 1975)
P. (Neopisidium) cruciatum Sterki (Sterki, 1916)
P. (N.) punctatum Sterki (Hinkley, 1916)
P. (Pisidium) dubium (Say) (Sampson, 1893, 1894; Hinkley, 1916)

[1]Endemic Interior Highlands species restricted to the Ozark Plateaus and some adjacent areas.
[2]Endemic Interior Highlands species restricted to the Ouachita Mountains.
[3]Endemic Interior Highlands species.

16. The first four listed *Pisidium* (see Table 3) are confirmed identifications (Gordon et al. 1980c). The remaining species are provisionally included on the authority of the references following the species name.

DISCUSSION

The geographical distribution of species richness in mollusks is similar to that of crayfish (see Hobbs *in* Pennak, 1978). The development of the North American molluscan fauna appears to have been centered in the highlands (Cumberland Region) of the southeastern United States (Walker, 1917; van der Schalie and van der Schalie, 1950); although, an old world derived fauna is prevalent west of the Continental Divide (Simpson, 1895; van der Schalie and van der Schalie, 1950). The number of species that have inhabited the Cumberland Region has been illustrated by Ortmann (1924, 1925) and van der Schalie (1939). Walker (1917), van der Schalie and van der Schalie (1950), Johnson (1978), and Gordon et al. (1980b) have shown that the Cumberland Region and the Interior Highlands are geologically related, have been physically connected, and were influenced by similar factors (e.g. geological uplifts, isolation, geographical shift of river systems). The past connection with the Cumberland Region, the geological age of the Interior Highlands, and their function as a biological refugium during the Cretaceous and Pleistocene (Gordon et al. 1980b) have resulted in the development of a diverse molluscan fauna in Arkansas. This fauna is distinguished by endemic species and relict populations.

The primary component of the present Arkansas mollusks is from the Interior Basin or Mississippian fauna. Endemism of the Mollusca within the Interior Highlands has been somewhat limited when compared to the Cumberland Region. However, distinct trends are represented for several groups. Fifteen terrestrial gastropods have been listed as endemic (see Table 1). Of these, the majority of species are from the family Polygyridae and are primarily restricted to the Ouachita Mountains. Species, such as *Mesodon magazinensis* and *Stenotrema pilsbryi*, are restricted to single mountains (e.g. Mt. Magazine and Rich Mountain, respectively). The Hydrobiidae contains most of the endemic aquatic Gastropoda. In the Ozark Plateaus, several endemic hydrobiids have adapted to cave environments (Hubricht, 1950, 1979; Nordstrom et al. 1977). The endemic, epigean hydrobiids appear to be known only from their type localities. At present, no endemic sphaeriids are known. However, a varied endemic unionid fauna has persisted, primarily within the Lampsilinae. This is fairly consistent with the Cumberland fauna; although, to a lesser degree. The Cumberland association is supported by the endemic *Fusconaia ozarkensis*, which Ortmann (1917) grouped with the Cumberlandian *F. barnesiana*. Other Cumberland affinities include relict populations of *Cumberlandia monodonta*, *Dysonmia triquetra*, *D. florentina* (formerly *Truncilla curtisii* Frierson and Utterback), *D. turgidula* (formerly *T. lefevrei* Utterback), and the presence of several pleurocerid species, including the endemic *Goniobasis potosiensis*. Other relicts, but of a southern origin, may include *Lampsilis streckeri* and *Arkansia wheeleri*. Needs for further study are indicated by recent faunal additions (Hubricht, 1979; Gordon et al. 1980c) and have been addressed by Gordon et al. (1980b).

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POTENTIAL OF UTILIZING SCRAP PROCESSED CHEESE AS A MAJOR RATION COMPONENT FOR CHANNEL CATFISH*

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ABSTRACT

Three cages (0.9 m³) were stocked with 200 channel catfish, *Ictalurus punctatus* Rafinesque, fingerlings (73.7 g avg.) in a 1.5 hectare pond. Two cheese rations were formulated and fed to the catfish; the first consisting of cheese, oil, and vitamin C (C + VC) and the second consisting of cheese, cottonseed meal, oil, trace minerals, and vitamins (CC + VM). A commercial trout ration (TC) was fed as a control.

High mortalities occurred in the C + VC diet, thus resulting in premature removal of that cage from the study (after 86 days). A sample of 50 fish from the two remaining cages, along with harvest data from the C + VC diet, revealed a 45.6% difference in average fish weight between the C + VC and CC + VM diets, a 63.5% difference between the C + VC diet and TC ration, and 32.9% difference between the CC + VM diet and TC ration. Final harvest of CC + VM and TC cages was completed after 134 days. Comparisons revealed that a 38.3% difference in average fish weight existed between these two diets. Statistical analysis of data indicated that fish fed the CC + VM diet had a significantly lower percentage dress-out weight and a significantly higher amount of mesenteric fat. This experiment does suggest that cheese scraps, when properly balanced with other essential ingredients, may be utilized as a major component of catfish rations.

INTRODUCTION

Cheese generally has been limited in use to the sport fishing bait industry. Recently, several farming operations in Arkansas have expressed interest in this product because of the relatively low cost and local availability. Scrap cheese, a by-product of the cheese industry, is composed of trimmings and off-color and off-flavor cheeses. Several cheese buyers pass through the catfish region as they supply the bait industry. These same individuals could easily supply many catfish farming operations. With the thrust of feed research striving for least-cost formulation of diets (Robinette, 1977) cheese scraps are an attractive option.

There is no published information on the use of cheese as a major component of fish rations. However, research is presently being conducted at the Franklin Institute (Pennsylvania) involving cheese as a ration component for channel catfish. Due to a lack of information about cheese use in fish rations, a pilot study was initiated in 1979 utilizing scraps as a food source for caged channel catfish at the University of Arkansas at Pine Bluff (UAPB).

METHODS AND MATERIALS

Three 0.9 m³ cages as described by Newton and Merkowsky, 1976, were anchored in a 1.5 hectare pond. A 27.3 by 43.2 cm pan with a 11.4 cm high food retaining ring (Vexar-0.32 cm mesh) attached to the edges was suspended by wires in two of the cages with the top of the retaining ring located 10 cm below the surface of the water.

Three rations were utilized during the study. Two cheese diets were especially formulated for two cages of catfish. One consisted of scrap cheese, commercially available vegetable cooking oil, and vitamin C (ascorbic acid) (C + VC) with the percentage of each ingredient (by weight) being 95.75, 4.20, and 0.05, respectively. Ascorbic acid, which is essential for catfish rations (Lovell, 1973) was added to the C + VC diet because cheese has an inadequate amount of this vitamin. Cheese, cottonseed meal, vegetable oil, trace minerals (U.S.P. XIV salt mixture) and a commercial vitamin premix (Mountaire Vitamins, Inc.) constituted the second formulation (CC + VM) with the percentage of each (by weight) being 74.00, 18.25, 4.00, 3.50, and 0.25, respectively. The diet was minimally adjusted (purposely) so that growth rates could be established on the basis of cheese scraps only. Commercially available vegetable oil was used as a binder for the other ingredients incorporated into the cheese rations. The third cage of catfish was fed a commercially available trout ration (TC) with a caged catfish performance record established in a previous study at UAPB (Newton and Dean, 1978).

Cages were stocked on 21 June, 1979 with 200 channel catfish weighing an average of 73.7 grams. All fish were preconditioned in the cages 11 days (6 feeding days) on the TC ration with the experimental diet tests beginning on 2 July. Average fish weight and water temperature determined the amount of ration fed, and adjustment of quantity was estimated on a weekly basis (based on monthly samples). Cheese diets were mixed one week in advance and refrigerated. Each cheese ration was separated into three portions and placed in the feeding pans. All uneaten portions remaining from the preceding day were weighed and recorded. Mortality and water temperatures were monitored daily.

A 5% (minimum) sample of fish from each diet was weighed monthly to estimate average fish gain. At harvest, samples consisting of the first 16 individuals captured were removed for individual body weights and dress-out weights. Mesenteric fat was also weighed to determine if any diet related differences existed. A Student's t test (Steel and Torrie, 1960) was used to compare differences in means of total fish weight, dress-out weight, dress-out percentage, mesenteric fat, and percent of mesenteric fat of fish fed the C + VC and TC diets. Percent moisture of each ration was determined by placing weighed samples in a Blue M drying oven for 48 hours at 100°C. Samples then were removed and weighed to determine percent moisture.

*Published with the approval of the Director of the Arkansas Agriculture Experiment Station.

RESULTS AND DISCUSSION

Fish Harvest: Fish on the C + VC diet were harvested prematurely due to high mortalities. After 86 days fish from the C + VC diet cage were harvested, and 50 fish were weighed from each of the remaining test cages. Figure 1 reveals the average fish weights as determined from monthly sample data. There was a 45.6% difference in average fish gain between the C + VC and CC + VM diets, a 63.5% difference between the C + VC diet and TC ration, and a 32.9% difference between the CC + VM diet and TC ration. Fish fed the C + VC diet initially gained weight, and then lost, as was evidenced by final harvest. Food conversion efficiency (FCE) after 86 days was estimated, based on recorded data to be 2.5:1, 3.1:1, and 7.6:1 for the TC ration, CC + VM diet, and C + VC diet, respectively (wet weight basis). Temperature data (Fig. 1) correlated well with growth of the fish on the TC ration and the CC + VM diet. The above data indicated that cheese scraps cannot be used alone as a complete source of nutrition for caged catfish production.

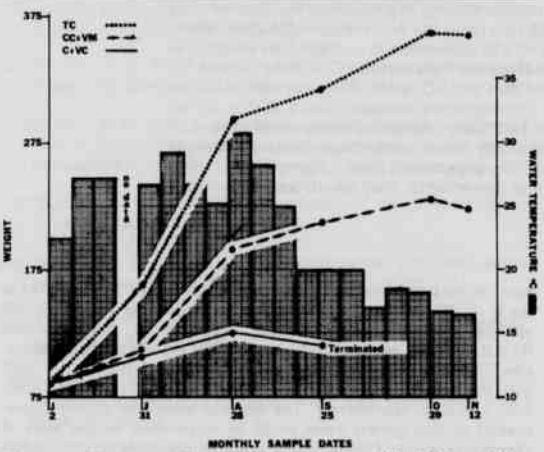

Figure 1. Mean monthly growth of channel catfish fed three different rations. (Average weekly surface temperature data included.)

Final Harvest: Harvesting of the remaining two cages of fish was accomplished after 134 days. a 38.3% difference in average fish weight existed between the CC + VM diet and TC ration (Fig. 1). Harvest data was statistically compared, and the results were recorded in Table 1. Since such a large disparity existed between the average mean weight of fish from the two samples, individuals in the same weight class (215-325 g) were selected for statistical comparisons. There was no significant difference in the mean total fish weight of the subsamples from each ration; however, there was a significant difference between means for dress-out percentage, mesenteric fat, and percent of mesenteric fat (Table 1). Page and Andrews (1973) and Lovell (1979) found that diets with high calorie concentrations resulted in decreased consumption. Feeding records and observations indicated that at least some portion of the CC + VM diet remained in the cage for a period of 24 hours 31 of 81 total feeding days. Lovell et al. (1974) found that body protein percentages were inversely related to body fat content. Results indicated that the high fat content (22.9%) of the CC + VM diet satisfied energy requirements but adversely affected the percent of body protein in the catfish fed that diet (Table 1). High fat content of the feed and/or cooling water temperatures may have led to the leveling out of growth of fish on the CC + VM diet (Fig. 1) during the latter part of the study. This study and the results of the above mentioned investigations suggest that scrap cheese may be used as a ration component but in reduced amounts due to the high fat content.

Table 1. Comparison of channel catfish raised on two diets based on a 16-fish sample and 8-fish weighing between 215-325 g.

DIETS	TOTAL WEIGHT IN GRAMS	DRESSED WEIGHT IN GRAMS	PERCENT DRESS-OUT	MESENTERIC FAT IN GRAMS	PERCENT MESENTERIC FAT
			16-Fish		
TC	345.0 a[1/]	200.5 a	57.3 a	10.28 a	2.89 a
CC + VM	243.4 b	119.4 b	49.2 b	8.89 a	3.61 b
			8-Fish		
TC	273.1 a	146.9 a	53.5 a	7.10 a	2.55 a
CC + VM	278.8 a	133.8 a	48.1 b	9.35 b	3.39 b

[1]Means followed by different letters are significantly different at the 0.05 level.

Moisture: Percent moisture of the three diets was 10, 26, and 32 for the TC, CC + VM, and C + VC diets, respectively. Adjustment for moisture with respect to the amount of ration offered the catfish in the cheese diets was made on 20 August. Amounts fed to fish on the cheese diets were adjusted to equal the wet weight fed to the TC diet fish. Poston (1974) found that brown trout *(Salmo trutta)* fed diets containing 9.6% and 55.0% moisture grew at nearly the same rate when fed on a dry weight basis. Results of the present study were inconclusive with respect to the effect on weight gain made by the levels of moisture in the diets. Future studies with high moisture diets should reflect consideration of moisture as a variable in ration design.

Mortality and Antibiotics: Total survival at harvest for the C + VC diet fish was 72%, while survival for the TC ration and CC + VM diet fish was 82 and 96%, respectively. Bacterial problems caused mortality in the TC ration and CC + VM diet cages, therefore, an approved antibiotic (Tetracycline Hydrochloride) was incorporated into the feed mixtures. During two reoccurring incidents of bacterial infection, the fish fed the medicated TC ration consumed only a small amount on the first and second feeding days, while fish fed the CC + VM diet immediately consumed all of their medicated ration. Mortalities ceased to occur among the CC + VM diet fish more rapidly than in the TC ration fish. This observation suggests that a cheese-antibiotic mixture might be more readily accepted than the medicated pellets by diseased fish. Diseased fish that can be brought back on feed quickly will recover faster and thus will resume growth more rapidly. Further research on the appeal of cheese as an attractant and as a binding mixture for antibiotics should be conducted.

Ration Preparation: Preparation of cheese diets requires considerable time; however, mixing large batches of ingredients would be more feasible with proper equipment. The size of a commercial catfish operation may be a limiting factor in production of cheese-based rations due to the frequency and necessity of mixing feed batches.

These results indicated that cheese scraps cannot be utilized as a single source of nutrition for caged channel catfish production. Cheese should not be used at the level incorporated in the CC + VM diet because of the high fat content. Fish growth was attained with cheese, so it may be assumed that a relatively high percentage of cheese may be incorporated into a ration designed for channel catfish production. Finally, observations indicated that cheese may be effective as a medium for antibiotics in the treatment of some internal bacterial diseases of catfish.

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INFLUENCE OF GENDER APPROPRIATENESS OF SEX-ROLE AND OCCUPATIONAL PREFERENCES ON EVALUATIONS OF A COMPETENT PERSON

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ABSTRACT

Previous research has found that while masculine sex-role preferences are more highly valued, persons holding gender consistent sex-role preferences generally are rated as more attractive. The present study explores the interactive effect of gender consistent/inconsistent sex-role preferences and congruent/incongruent occupational choices on evaluations of a person from varying perspectives. Statistical analysis of the data revealed (1) people holding masculine sex-role preferences are perceived to have a higher motivation to succeed, and to be more competent; (2) from the perspective of friend and potential employee, persons holding gender consistent sex-role preferences are perceived as more attractive; (3) from the perspective of potential employer, there is a tendency for males to prefer employees who hold masculine sex-role preferences, while females continue to prefer gender consistent sex-role preferences.

INTRODUCTION

As a result of the women's liberation efforts, a number of traditional sex barriers to employment and advancement by women into more prestigious and powerful positions have been crossed. There also has been a concommitant increase in the number of males seeking employment in positions that were traditionally viewed as feminine pursuits (eg., nursing). To the extent that this shift of vocational roles is likely to continue, it becomes important to know how these persons are likely to be perceived by peers, co-workers, and employers. While job opportunity can be legislated, social acceptance cannot.

An important variable that might be expected to influence employer/employee, as well as social, acceptance is the extent to which males and females maintain the traditional sex-role preferences irrespective of their occupational choice. Broverman et al. (1972), after reviewing the relevant literature, concluded that people do have clearly defined sex-role stereotypes of men and women and further, the characteristics that are ascribed to men are more positively valued than those that are ascribed to women.

A logical question is then, would women be well advised to assume the more positively valued masculine traits. Seyfried and Hendrick (1973) found that while there is a preference for congruence between a person's sex and their sex-role preferences, this preference is moderated by a preference for masculine sex-role attitudes leading these researchers to conclude that there is a greater lattitude of acceptance for women than for men with respect to the adoption of sex-role preferences. Subsequent findings by Shaffer and Wegley (1974) indicate that to the extent that females adopt masculine sex-role preferences, they should serve as modifiers or be supplementary to their basic feminine being.

With regard to males, O'Leary and Donohue (1978) found that college students actually rated a feminine male who aspired to a "feminine" occupation (i.e., kindergarten teaching) to be more desirable as a work partner than a masculine male who aspired to a traditionally "masculine" occupation (i.e., business). However, the implications of these data are clouded by the fact that their masculine and feminine occupations differed along a dimension other than masculinity/feminity that could account for the favoritism shown to the feminine male (i.e., kindergarten teaching may be viewed as more prosocial and less self-serving than a career in business).

In the present experiment, masculine and feminine males were described as aspiring to either a traditionally masculine or traditionally feminine occupation that presumably did not differ in its prosocial implications (i.e., both the masculine and the feminine occupations were positions within a large corporation). Based on the extremely negative reaction to feminine males reported by Seyfried and Hendrick (1973), we predicted that subjects would prefer the masculine to the feminine male on measures of the stimulus person's social attractiveness and desirability as a prospective employee. However, it seemed reasonable to expect that subject's derogation of feminine males might be moderated somewhat on the employee attractiveness measure if the male stimulus person aspired to a traditionally feminine occupation. In this particular instance, it is the feminine male who is likely to be judged as having the interests and attributes that will facilitate job performance.

METHODS AND MATERIALS

A total of 160 students, 80 males and 80 females, served as subjects for partial fulfillment of an introductory psychology course requirement. An equal number of subjects by sex were provided with information characterizing either a male or female stimulus person as having either masculine or feminine attitudes, and as having opted for what would be traditionally considered either a masculine or a feminine occupation.

Subjects (Ss) were run in groups of four. Upon arrival they were told they would be participating in a study concerned with assessing the degree of accuracy of impressions of others on the basis of limited information. To increase impact, it was mentioned that law and graduate school admission committees, as well as various corporations, often have to make selections on the basis of very limited information about the candidates, and when incorrect decisions were made, they often prove very costly. Ss were then told that they would receive a small portion of the information about the stimulus person. What was presumably of interest was the degree to which subjects,

evaluations, based on limited information, paralleled the evaluation based on more complete information.

Subjects were then provided with a brief biographical sketch, which was constant across all conditions except for the person's name, either Beverly or Bill Davis, and their occupational preference within the telephone company, either an installer (traditionally masculine) or an operator (traditionally feminine). Manipulation of sex-role preferences was accomplished by providing Ss with a copy of the presumed responses of the stimulus person on a "Social-Emotional Preference Test" which indicated either a masculine or a feminine response on 18 of 20 sex-role related attitudes, eg., "On a date I would rather not have to decide where to go" (yes = feminine response). Ss then completed an "interpersonal rating form," which included manipulation checks and a number of items assessing the attractiveness of the stimulus person from the perspective of friend, employer, employee, and co-worker.

RESULTS

Manipulation Checks and General Impressions: An item, "How appropriate were the person's responses on the Social-Emotional Preferences Test for a member of his/her sex?" was intended as a check on the manipulation of the stimulus person's (SP's) sex-role preferences. The ANOVA on this item produced a disordinal Sex of SP × Sex-role preference interaction, ($F = 133.41$, 1/144 df on this and subsequent F ratios, $p < .001$), indicating gender consistent responses were thought to be more appropriate. Thus, sex-role preferences were successfully varied.

Analyses of the questions "How appropriate is the person's present job for a member of his/her sex?" and "How appropriate are the person's occupational aspirations for a member of his/her sex?" indicated that the occupational preferences of SP's were successfully varied. As anticipated, subjects' responses to each question produced a disordinal Sex of SP × Occupational preferences interaction (for present job, $F = 53.66$, $p. < .001$); for future aspirations, $F = 16.79$, $p. < .001$). The pattern of the interaction was identical for both questions: Subjects perceived the occupational preferences of male SP's to be more appropriate if they were masculine rather than feminine, and the occupational preferences of female SP's to be more appropriate if they were feminine rather than masculine.

On an absolute basis, the attempt to portray the SP's as competent was successful ($M = 5.67$ out of 7.00 possible). However, subjects thought that SP's with masculine sex-role preferences were more competent ($M = 5.88$) than SP's with feminine sex-role preferences ($M = 5.46$), $F = 4.46$, $p < .05$.

Finally, an ANOVA of subjects' responses to the question "How motivated is this person to succeed at a career?" yielded a main effect for the sex-role preferences manipulation, $F = 16.40$, $p < .001$. SP's with masculine sex-role preferences were judged to be significantly more career oriented ($M = 5.61$) than were SP's with feminine sex-role preferences ($M = 4.70$).

Attraction Measures: ANOVA of Ss ratings of liking of the SP's and of their social attractiveness (as a date, friend, etc.) both produced significant disordinal Sex of SP × Sex-role preference interactions (for liking of, $F = 22.44$, $p < .001$; for social attractiveness, $F = 16.23$, $p < .001$). These interactions indicated that SP's of each gender were rated more favorably when their sex-role preferences were "gender consistent."

An analysis of SP's ratings of SP's attractiveness as a co-worker produced only one significant outcome, a disordinal Occupational preference × Sex of subject interaction ($F = 11.53$, $p < .001$), with males indicating a clear preference for working with SP's who favored a masculine rather than a feminine job, whereas females showed an equally strong preference for working with SP who favored a feminine over a masculine job.

Analyses of Ss ratings of SP's attractiveness as a prospective employee and as a prospective supervisor yielded significant Sex of SP × Sex-role preference interactions (for employee, $F = 14.29$, $p < .001$; for supervisor, $F = 6.86$, $p < .01$). These interactions revealed severe derogation of males holding feminine sex-role preferences. From the perspective of the employer, there was also a marginally significant Sex of SP × Sex-role preference × Sex of S interaction ($F = 3.19$, $p < .08$), with males preferring masculine sex-role preferences while females preferred gender consistent sex-role preferences.

DISCUSSION

Regarding the subject's evaluations of the SP's from varying perspectives it was found that Ss indicated greater liking of, and a preference as a friend, supervisor, and potential employee, the stimulus persons with gender consistent sex-role preferences. Each of these interactions reflected a comparable pattern with the feminine male being evaluated least favorably. These results are consistent with Seyfried & Hendrick's (1973) conclusion that while there is a preference for gender consistent sex-role preferences, there exists a greater latitude of acceptance for women than for men regarding the adoption of sex-role preferences.

While the above findings would suggest that people, especially males, would be well advised to maintain traditional sex-role preferences, the triple-order interaction on the item concerned with evaluation of the S from the standpoint of a prospective employer indicates that while females continue to prefer persons who maintain gender consistent sex-role preferences, males show a preference for persons holding masculine sex-role preferences. To the extent that males continue to hold a disproportionate number of supervisory positions, this finding could have important practical implications for women entering the job market. Furthermore, the data suggest that the reason males preferred persons holding masculine sex-role preferences is that persons holding masculine sex-role preferences were considered to be more career-oriented and more motivated to succeed at a career.

Finally, while the present results do not provide a direct test of the proposed alternative explanation of the O'Leary and Donohue (1978) results, the consistent derogation of males holding feminine sex-role preferences across role relationships, regardless of occupational preference, would at least strongly suggest the critical role of the prosocial implications of their traditionally feminine occupation. Furthermore, the present results did not find any support for the possibility that the derogation of males holding feminine sex-role preferences would be attenuated given a congruent occupational choice.

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THE WATER STRIDERS (HEMIPTERA: GERRIDAE) OF ARKANSAS

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ABSTRACT

The taxonomy, distribution, and ecology of the water striders of Arkansas are discussed based on personal collections, museum specimens, and literature records. A total of 15 species representing six genera is presently known from the state. One additional species is included as probably occurring in Arkansas.

INTRODUCTION

Most studies on the Gerridae of Arkansas have been limited to scattered locality records which are cited under the appropriate species. Kittle (1974, 1977a) reported on the biology of those species occurring in Washington County, and Kittle (1977b) included numerous records of *Trepobates* spp. from Arkansas. The purpose of the present paper is to contribute additional knowledge of the taxonomy, ecology, and distribution of this neglected family of insects in Arkansas.

METHODS AND MATERIALS

Information on the Gerridae of Arkansas was gathered primarily through personal collections, especially in northwest Arkansas, and also from museum specimens and the literature. Approximately 5800 specimens were collected from 1972 through 1977, and 720 specimens were examined from the following institutions and individuals: Arkansas State University, Arkansas Tech University, Harold C. Chapman, Iowa State University, John T. Polhemus, Memphis State University, Purdue University, United States National Museum, University of Arkansas at Fayetteville, University of Kansas, and University of Southwestern Louisiana. Records were gathered for 58 of the 75 counties in Arkansas.

RESULTS AND DISCUSSION

Key to the Genera of Gerridae of Arkansas

1. Inner margins of eyes sinuate or concave behind the middle; body comparatively long and narrow 2
   Inner margins of eyes convexly rounded; body comparatively short and broad 4
2(1). Basal segment of fore tarsus about half as long as second; dorsal surface of head and pronotum glabrous, shiny ..... *Neogerris*
   Basal segment of fore tarsus subequal in length to second; dorsal surface of head and pronotum sericeous, dull 3
3(2). Antennal segment 1 shorter than segments 2 and 3 together ..... *Limnoporus*
   Antennal segment 1 equal to or longer than segments 2 and 3 together ..... *Gerris*
4(1). Antennal segment 1 long, longer than (male) or subequal to (female) 2, 3, and 4 united ..... *Metrobates*
   Antennal segment 1 much shorter than 2, 3, and 4 united 5
5(4). Middle femur distinctly longer than hind femur; antennal segment 2 very short, its length less than three times its diameter ..... *Rheumatobates*
   Middle femur distinctly shorter than hind femur; antennal segment 2 long, its length at least five times its diameter ..... *Trepobates*

Gerris Fabricius

Four species of this genus are known to occur in Arkansas. *Gerris insperatus* is included in the following key as a species which will probably be found in Arkansas in the future.

Key to the Species of *Gerris* in Arkansas

1. First genital segment not divided ventrally (males) 2
   First genital segment divided into two halves which meet along ventral midline (females) 6
2(1). Sixth abdominal ventrite singly emarginate at apex and with a broad median furrow ..... *G. nebularis*
   Sixth abdominal ventrite doubly emarginate at apex and without a broad median furrow 3
3(2). Length 12 mm or more; first genital segment with a strong keel ventrally ..... *G. remigis*
   Length 11 mm or less; first genital segment with keel moderately or weakly produced 4
4(3). Anterior lateral margin of pronotum with a pale stripe immediately posterior to eye ..... *G. argenticollis*
   Anterior lateral margin of pronotum without a pale stripe immediately posterior to eye 5
5(4). Venter of first genital segment strongly impressed on each side of median ridge, a distinct keel present ..... *G. marginatus*
   Venter of first genital segment not strongly impressed on each side of median ridge, a distinct keel absent ..... *G. insperatus*
6(1). Length 14 mm or more 7
   Length 12 mm or less 8
7(6). Connexival spines long, reaching to or slightly beyond apex of abdomen ..... *G. nebularis*
   Connexival spines short, reaching only to apex of first genital segment ventrally ..... *G. remigis*
8(6). Anterior lateral margin of pronotum with a pale stripe immediately posterior to eye ..... *G. argenticollis*
   Anterior lateral margin of pronotum without a pale stripe immediately posterior to eye; females so similar they cannot be reliably separated with a key ..... *G. insperatus* and *G. marginatus*

Gerris argenticollis Parshley

This species was collected from a variety of habitats including ponds, small lakes, borrow pits, and quiet pools of streams, but was most abundant on woodland pools. Collection dates ranged from 12 March to 12 June. *G. argenticollis* often was associated with *G.*

marginatus and *Limnoporus canaliculatus*. All specimens were macropterous. The species was first recorded from the state by Kittle (1977a), but is apparently widespread. Records exist for these counties: Arkansas, Ashley, Calhoun, Cleveland, Columbia, Crawford, Dallas, Franklin, Lonoke, Montgomery, Newton, Polk, Searcy, Stone, Union, and Washington. *G. argenticollis* may be locally common but is a rare species in general. Eighty-five specimens were examined.

Gerris insperatus Drake and Hottes

This gerrid has not been recorded from Arkansas but is included here because of the probability that it eventually will be collected in the state. I have specimens in my collection from Cass Co., Texas, approximately 34 km west of the Arkansas state line. The species should be looked for in spring or early summer.

Gerris marginatus Say

This water strider was euryecious and was collected from the following habitats: ponds, lakes, woodland pools, streams, springs, temporary pools, roadside ditches, and borrow pits. It occurred on almost every body of water visited during the spring. Most habitats from which specimens were taken were permanent, but many were ephemeral. One specimen was collected at a blacklight in Union Co. *G. marginatus* was collected from 17 February to 29 October, but the majority of records were from April, May, and June. Habitats which supported large populations of this species in the spring were often uninhabited in late summer and autumn. The species was observed in association with *G. argenticollis*, *G. remigis*, *Limnoporus canaliculatus*, and *Trepobates subnitidus* but was often found alone. Of the 817 adults examined, 802 (98%) were macropterous and 15 (2%) were brachypterous.

Kuitert (1942) recorded *G. marginatus* from Arkansas, and McGary and Harp (1972) and Harp and Hubbard (1972) reported this species from Cleburne Co. and Saline Co., respectively. It is abundant in spring and early summer, is widespread in the state, and has been recorded from the following counties: Arkansas, Ashley, Baxter, Benton, Clark, Cleburne, Craighead, Crawford, Crittenden, Cross, Dallas, Desha, Drew, Faulkner, Fulton, Greene, Hempstead, Hot Spring, Jackson, Johnson, Lawrence, Madison, Marion, Mississippi, Montgomery, Newton, Pike, Polk, Pope, Randolph, Saline, Scott, Searcy, Sharp, Stone, Union, Washington, and Woodruff.

Gerris nebularis Drake and Hottes

This species mainly inhabited large, quiet pools of medium and large streams but sometimes was found on small streams. It was restricted to lotic habitats. Collection dates ranged from 1 April to 15 October. *G. nebularis* often was associated with *G. remigis*. Of the 150 specimens examined, 141 (94%) were brachypterous and nine (6%) were macropterous. This water strider was reported from Arkansas by Drake and Harris (1934). *G. nebularis* is undoubtedly more widespread in Arkansas than is indicated by the following county records: Baxter, Benton, Carroll, Clark, Columbia, Fulton, Hempstead, Lonoke, Pike, Randolph, Sharp, and Washington. The species may be locally common but is more difficult to collect than most gerrids because of its wariness and microhabitat (middles of pools of larger streams).

Gerris remigis Say

This gerrid usually was recorded from small permanent streams but also was common on medium and large streams. It rarely was observed on ponds, roadside ditches, or woodland pools. *G. remigis* was collected from a stream in the twilight zone of Logan Springs Cave, Benton Co., and McDaniel and Smith (1976) reported the species from the twilight zone of Needles Cave, Izard Co. It was recorded for each month of the year, but the majority of collections were made from April through October. *G. remigis* sometimes was observed in association with *G. marginatus* and *G. nebularis*, but often occurred alone. Of the 751 adults examined, 676 (90%) were apterous and 75 (10%) were macropterous.

The species is abundant and widespread in the Interior Highlands but is apparently rare or absent from most of the Gulf Coastal Plain. The disjunct Arkansas Co. record may in fact be in error. It is based on a specimen in the University of Arkansas at Fayetteville collection which bears a label "black light trap", but the specimen is apterous. *G. remigis* was recorded from these counties: Arkansas, Baxter, Benton, Conway, Crawford, Franklin, Fulton, Greene, Independence, Izard, Johnson, Lawrence, Logan, Madison, Marion, Montgomery, Newton, Polk, Pope, Randolph, Scott, Searcy, Stone, and Washington.

Limnoporus Stal

Limnoporus canaliculatus (Say)

This species was formerly placed in the genus *Gerris*, subgenus *Limnoporus*, but Andersen (1975) elevated the subgenus *Limnoporus* to generic status. Cather and Harp (1975) reported *L. dissortis* (as *Gerris*) from northeast Arkansas, but this record probably applies to *L. canaliculatus*. *L. canaliculatus* was euryecious and was collected from the following habitats: lakes, ponds, woodland pools, borrow pits, temporary pools, and pools of small, medium, and large streams. Seventeen specimens were collected at a blacklight in Miller Co. The species was collected from 15 January to 25 November and was often associated with *G. marginatus* and *G. argenticollis*. One hundred seventy-two (79%) of the 217 specimens examined were macropterous and 45 (21%) were apterous.

L. canaliculatus was recorded from Little Rock by Drake and Harris (1928), from Arkansas by Kuitert (1942), and from Cleburne Co. by McGary and Harp (1972). This water strider is widespread in Arkansas and was recorded from the following counties: Arkansas, Ashley, Benton, Clark, Cleburne, Craighead, Crawford, Crittenden, Dallas, Desha, Drew, Faulkner, Greene, Hempstead, Jackson, Madison, Miller, Mississippi, Montgomery, Nevada, Newton, Pope, Pulaski, Randolph, Scott, Sevier, Union, Washington, and Woodruff. It was locally common, especially on lentic habitats.

Metrobates Uhler

Key to the Species of *Metrobates* in Arkansas

1. First genital segment not divided ventrally (males) 2
   First genital segment divided into two halves which meet along ventral midline (females) 3
2(1). With a single spur on the midline of the mesosternum ..... *M. alacris*
   Without a mesosternal spur. ..... *M. hesperius*
3(1). Light pronotal marking a broad stripe ..... *M. alacris*
   Light pronotal marking more or less oval or circular. ..... *M. hesperius*

Metrobates alacris Drake

M. alacris was collected only from streams in July and September. Kittle (1977c) first recorded this species from Arkansas. Although it is known only from two localities in Greene and Hempstead counties, *M. alacris* is probably locally common on many of the streams of the Gulf Coastal Plain. Twenty-one apterous specimens were examined.

Metrobates hesperius Uhler

This water strider was collected only from larger streams and usually was found either immediately above or below riffle areas.

Collection dates ranged from 25 June to 21 October. This species was gregarious but was not closely associated with any other gerrid. All specimens were apterous. *M. hesperius* was reported from Arkansas by Anderson (1932). It was found to be widely distributed in the Interior Highlands and was recorded from the following counties: Baxter, Benton, Carroll, Fulton, Independence, Lawrence, Madison, Marion, Montgomery, Newton, Pike, Polk, Randolph, Saline, Scott, Stone, and Washington. *M. hesperius* was locally common, and 409 specimens were examined.

Neogerris Matsumura

Neogerris hesione (Kirkaldy)

This species was formerly placed in the genus *Limnogonus*, but belongs in *Neogerris* according to the treatment of Andersen (1975). *N. hesione* usually was collected from permanent ponds and lakes, but macropterous specimens were occasionally taken from pools of streams. Adults were collected from 22 May to 3 November. *N. hesione* was highly gregarious and was often associated with *Trepobates subnitidus*. Of the 182 adults examined, 163 (90%) were apterous and 19 (10%) were macropterous. This gerrid was recorded from Arkansas by Drake and Harris (1934). It was locally common at localities scattered throughout the state and was recorded from these counties: Craighead, Crawford, Faulkner, Fulton, Greene, Mississippi, Montgomery, Randolph, Scott, Sharp, Union, and Washington.

Rheumatobates Bergroth

Key to the Species of *Rheumatobates* in Arkansas

1.	Antennae geniculate, with spines (males)	2
	Antennae not geniculate, without spines, cannot be adequately keyed at present	females
2(1).	Hind femur straight	*R. tenuipes*
	Hind femur curved, often thickened	3
3(2).	Hind femur with long hairs on the basal third of the inner margin	*R. palosi*
	Hind femur without long hairs on the basal third of the inner margin	4
4(3).	Middle femur with a row of long straight hairs on inner margin	*R. hungerfordi*
	Middle femur hairless on inner margin except for a few hairs near apex	*R. trulliger*

Rheumatobates hungerfordi Wiley

This water strider was collected only from streams on 11 and 29 July. It was associated with *R. palosi*, *R. tenuipes*, and *Trepobates subnitidus*. *R. hungerfordi* was recorded from Polk Co. based on two female specimens (Hungerford, 1954). I collected the species from two localities in Hempstead and Sebastian counties. All 13 specimens examined were apterous.

Rheumatobates palosi Blatchley

Blatchley (1926) described this water strider as a variety of *R. rileyi*; however, Bobb (1974) elevated it to specific rank, and the latter classification is followed here. The species was collected from a variety of habitats including pools of large and small streams, lakes, ponds, and borrow pits. Collection dates extended from 20 May to 15 October. *R. palosi* was associated with several species of *Rheumatobates* and *Trepobates*. Of the 513 specimens examined, 502 (98%) were apterous and 11 (2%) were macropterous. *R. palosi* was reported from Carroll and Polk counties by Hungerford (1954) and from Arkansas by Schroeder (1931). It is the most widespread and abundant *Rheumatobates* in Arkansas and was recorded from the following counties: Ashley, Calhoun, Carroll, Clay, Cleveland, Columbia, Craighead, Crawford, Fulton, Hempstead, Johnson, Lawrence, Logan, Montgomery, Newton, Pike, Polk, Pope, Randolph, Saline, Scott, Sevier, Union, and Washington.

Rheumatobates tenuipes Meinert

This water strider usually was collected from pools of large streams, but one record was from a pond and one from a borrow pit. Collection dates ranged from 20 May to 15 October. *R. tenuipes* was associated with several species of *Rheumatobates* and *Trepobates*. Of the 223 specimens examined, only two (1%) were macropterous, and 221 (99%) were apterous. This gerrid was first recorded from Arkansas by Kittle (1977a). It is widely distributed and is occasionally locally common. Records were gathered for the following counties: Crawford, Fulton, Greene, Hempstead, Lawrence, Poinsett, Randolph, Sebastian, Union, and Washington.

Rheumatobates trulliger Bergroth

This species was collected only from pools of streams from 21 August to 23 September. It was associated with several species of *Rheumatobates* and *Trepobates*. Of the 24 specimens examined, 23 were apterous and one was macropterous. Literature records for *R. trulliger* in Arkansas include Arkansas (Schroeder, 1931), Polk Co. (Hungerford, 1954), and Craighead Co. (Cather and Harp, 1975). The species is known only from four localities in Craighead, Montgomery, Polk, and Washington counties and is apparently a rare species in Arkansas.

Trepobates Uhler

Key to the Species of *Trepobates* in Arkansas

1.	First genital segment not divided ventrally (males)	2
	First genital segment divided into two halves which meet along ventral midline (females)	4
2(1).	Antennal segment 3 with a basal row of long hairs, these hairs often appressed to segment	*T. knighti*
	Antennal segment 3 without long hairs	3
3(2).	Usually with a light yellow mesopleural stripe posterior to black postocular stripe of pronotum which is continuous between anterior and posterior margins	*T. pictus*
	Without a mesopleural stripe as described above	*T. subnitidus*
4(2).	Mesonotum prolonged posteriorly into a median, horn-like projection	*T. pictus*
	Mesonotum not prolonged posteriorly	5
5(4).	With a light mesopleural spot posterior to black postocular stripe of pronotum; antennal segment 2 distinctly shorter than 3	*T. knighti*
	Without a light mesopleural spot as described above; antennal segment 2 only slightly shorter than or subequal to 3	*T. subnitidus*

Trepobates knighti Drake and Harris

This gerrid inhabited pools of large, medium, and small streams and is apparently restricted to lotic habitats. One specimen was collected at a blacklight in Montgomery Co. Adult collection records in Arkansas ranged from 16 June to 25 October. *T. knighti* was commonly collected in close assocciation with *T. subnitidus*, *Rheumatobates palosi*, and *R. tenuipes*. Of the 1257 specimens examined, 1243 (99%) were apterous and only 14 (1%) were macropterous.

T. knighti was recorded from Arkansas by Drake and Harris (1932), Drake and Hottes (1952), and Drake and Chapman (1953). This gerrid is common on most streams in the Interior Highlands, and almost all collections were from this area. Specimens were examined from the following counties: Baxter, Boone, Carroll, Cleburne, Crawford, Fulton, Hot Spring, Independence, Johnson, Lawrence,

Logan, Madison, Marion, Montgomery, Newton, Pike, Polk, Randolph, Saline, Scott, Sharp, Stone, Van Buren, and Washington.

Trepobates pictus (Herrich-Schaeffer)

This species was collected from pools of small, spring-fed streams in Stone and Washington counties and from an unknown habitat in Cross Co. from 1 July to 12 September. *T. pictus* was associated with *T. knighti* and *Rheumatobates palosi* at the Washington Co. site. All 43 specimens examined were apterous. This gerrid was common at the single locality in Washington Co., but its abundance at the other two sites could not be determined.

Trepobates subnitidus Esaki

Females of this species may have the connexiva produced into short or long connexival spines or not produced into spines. In general, spineless females predominate in Gulf Coastal Plain populations and long-spined females predominate in Interior Highlands populations, with intermediate and mixed populations occurring in transitional areas. The long-spined populations were referred to as *T.* sp. by Kittle (1974, 1977a) because of their uncertain taxonomic status, but it was subsequently demonstrated (Kittle, 1977b) that long-spined populations were a morphological variant of *T. subnitidus*.

T. subnitidus was collected from lakes, ponds, borrow pits, and pools of large, medium, and small streams and was much more common on lentic than lotic habitats. Collection dates ranged from 20 May to 1 November. The species was commonly collected in association with *T. knighti, Gerris marginatus, Neogerris hesione,* and several species of *Rheumatobates*. Of the 1634 adults examined, 1502 (92%) were apterous and 132 (8%) were macropterous.

The record of *T. inermis* from Saline Co. (Harp and Hubbard, 1972) applies to *T. subnitidus*. *T. subnitidus* is widespread in Arkansas and is locally abundant. Records were gathered for these counties: Ashley, Benton, Boone, Calhoun, Clay, Cleburne, Cleveland, Craighead, Crawford, Desha, Faulkner, Fulton, Greene, Hempstead, Jackson, Johnson, Lawrence, Little River, Logan, Madison, Marion, Mississippi, Montgomery, Pike, Polk, Pope, Randolph, Saline, Scott, Sebastian, Sevier, Sharp, Union, and Washington.

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A PRELIMINARY INVESTIGATION OF THE GROUND-WATER RESOURCES OF BAXTER, FULTON, IZARD AND SHARP COUNTIES, ARKANSAS

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ABSTRACT

One hundred and seventy-seven drillers' well reports were used to investigate the groundwater resources of Baxter, Fulton, Izard, and Sharp counties. The most widely utilized aquifer zone is composed of the Cotter and Jefferson City dolomites. The well depths range from 30 to 740 ft with a mean and median of 264 and 225 ft, respectively. The drillers' yield estimates range from 1 to 50 gpm with a mean of 12.0 gpm and a median of 10 gpm. The piezometric surface has an average hydraulic gradient of 9 ft/mile with groundwater discharge occurring along the Spring and White Rivers.

Overlying the Cotter-Jefferson City aquifer is the Powell Dolomite aquifer. Well depths range from 43 to 275 ft with a mean and median of 137 and 114 ft, respectively. Driller estimated yields range from 7 to 40 gpm with a mean and median of 18 and 15 gpm, respectively. The Everton Aquifer is composed of a complex series of interfingering sandstones and carbonate layers that may act collectively or individually as aquifers. Well depths in this aquifer range from 8 to 812 ft with a mean of 338 ft and a median of 500 ft. Yields range from 1 to 40 gpm with a mean and median of 11 and 7 gpm, respectively. The least productive and least utilized, but shallowest aquifer is the St. Peter Sandstone aquifer which has a depth range of 55 to 113 ft with a mean and median of 80 and 85 ft, respectively. The yield ranges from 1 to 20 gpm with a mean and median of 9 and 5 gpm, respectively.

The Spearman Rank Correlation procedure was used to compare well yields (gpm), well depth, regolith thickness, depth to water, and piezometric surface elevation of the Cotter-Jefferson City aquifer. At $\alpha = 0.1$, the following relationships were established: 1) greater yield at shallow well depths, 2) greater yield where the water table is closer to the surface, 3) thicker regolith in deeper wells, and thicker regolith with increased depth to water. These correlations indicate the strong control on water movement by fractures in the aquifer, and "closing off" of fractures at depth, and the control of regolith thickness by depth to water rather than fracture proximity.

INTRODUCTION

Ground water is the primary source of water used by rural residents and small communities in northern Arkansas. Unfortunately, the number of ground water investigations in this area are extremely sparce. An early listing of some ground-water wells in northern Arkansas was made by Branner (1937) without any hydrogeologic interpretations. A very generalized statement of ground-water resources in Arkansas was made by Baker (1955). Lamonds (1972) performed a reconnaissance survey of northern Arkansas using limited data to produce piezometric surface maps for the Roubidoux Formation and Gunter Sandstone Member of the Gasconade Formation. Several University of Arkansas hydrologic theses have been written, but they have dealt almost exclusively with the Boone-St. Joe aquifer in the Fayetteville area. Ogden et al., (1979) have investigated deeper aquifers of Carroll, Madison, and Boone counties. A preliminary study similar in scope to this investigation of the ground-water resources of northern Searcy County recently has been prepared by Goodman and Ogden (1980).

This paper will present the preliminary results of a ground water reconnaissance survey of a four county area of north-central Arkansas where Ordovician carbonate and sandstone aquifers are widely utilized. The purposes of the paper are to: 1) define the aquifers, 2) determine ranges in yield and depths for the aquifers, 3) produce a piezometric surface map for the Cotter-Jefferson City carbonate aquifer, and 4) statistically compare aquifer and well properties.

LOCATION AND GEOLOGY

The study area is located in Baxter, Fulton, Izard, and Sharp counties of northern Arkansas (Fig. 1). The area is exclusively within the Salem Physiographic Province with Ordovician strata cropping out on the surface (Fig. 2). The strata dip gently southward along the southern flank of the Ozark Dome. The study area is relatively free of structural deformation with normal faults cutting the strata in a few areas. An extensive, but subdued, karst topography of many caves, dolines, and springs exist in the carbonate formations.

METHODS AND MATERIALS

Drillers' logs from 1970 to 1979 were acquired from the Arkansas Geological Commission for the four counties. One hundred and nine wells were accurately plotted on 7.5 minute topographic quadrangles using drillers' locations and county platt books. In this way, well top elevations and hence the elevation of the static water levels could be determined using water level information on the logs. The aquifer (producing horizon) of each well was determined from the geologic maps of the area in conjunction with the depth, producing zone, and gross lithologic log given on the drillers' well reports. Other information utilized from these reports was the estimated yield in gallons per minute (gpm) and regolith thickness.

The Spearman-Rank Correlation Coefficient Test of the Statistical

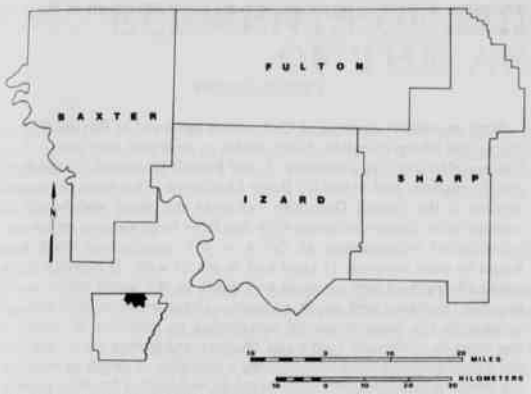

Figure 1. Location of study area.

SYSTEM	STAGE	FORMATION	THICKNESS (in ft.)	GENERAL ROCK TYPE
ORDOVICIAN	CINCINNATIAN	Cason	0-23	Shale
		Fernvale	0-125	Limestone
	MIDDLE ORDOVICIAN	Kimmswick	0-60	Limestone
		Plattin	0-240	Limestone
	LOWER ORDOVICIAN	Joachim	0-150	Dolomite
		St. Peter	0-175	Sandstone
		Everton	0-600	Dolomitic sandstone
		Black Rock	0-55	Dolomitic limestone
		Smithville	0-65	Limestone
		Powell	0-200	Dolomite
		Cotter	500+	Dolomite
		Jefferson City	300-400	Dolomite
		Roubidoux	135-190	Oolitic limestone
		Gasconade	100-200	Limestone

Figure 2. Generalized stratigraphy showing Ordovician formations of the study area (modified after Caplan, 1954, 1957).

Analysis System (Barr et al., 1976) was used to determine if relationships exists between various well and aquifer characteristics. The parameters compared were: 1) well depth, 2) depth to water, 3) regolith thickness, 4) yield (gpm), and 5) piezometric surface level (ft above sea leve).

RESULTS

Four aquifer zones above the Roubidoux are utilized by residents in the study area. The aquifer zones can be distinguished from marker horizons on the drillers' logs combined with the known surface geology, expected thicknesses of formations, and well depth. The shallowest of these Ordovician aquifers is the St. Peter Sandstone. This aquifer is the least utilized with producing wells located only in Sharp and Izard counties. The aquifer is unconfined, when exposed at the surface, but is confined when at depth. The St. Peter aquifer is also the least productive, having a range in yield from 1 to 20 gpm with a median and mean of 5 and 9 gpm, respectively (Table 1). Depth of wells producing from the St. Peter range from 35 to 113 feet with a mean and median of 80 and 85 feet, respectively (Table 1). The St. Peter Sandstone was included in the Evermore aquifer zone defined in northwest Arkansas by Ogden et al. (1979) due to its thinness or absence.

A second important aquifer is the Everton which is a carbonate and sandstone sequence underlying the St. Peter. The Everton Aquifer is slightly more productive than the St. Peter. It has a range in yield of 1 to 40 gpm with a median and mean of 7 and 11 gpm, respectively. Although more productive, the mean and median depth to water is considerably larger for the Everton than for the St. Peter. Well depths range from 80 to 812 feet with a mean and median depth of 338 and 500 feet, respectively (Table 1).

The Everton Formation is a complex aquifer zone composed of several water producing horizons separated by aquicludes. Everton sandstones and carbonates can occur as unconfined aquifers, when exposed at the surface, or confined conditions at depth. In general, the sandstones are tighter and less productive than the carbonates.

Below the Everton is the Powell Dolomite, the third major aquifer in the study area. The Powell is generally the most productive of the four aquifers. Well yields in this aquifer range from 7 to 40 gpm with a median of 15 gpm and a mean of 18 gpm. The depth of the wells ranges from 43 to 275 feet with a median and mean of 114 and 137 feet, respectively (Table 1). This aquifer is generally unconfined when exposed at the surface.

The Powell Dolomite increases in thickness in a southeastern direction across Arkansas (Caplan, 1957). Along the Arkansas-Missouri border, where the Powell is absent or thin, it does not act as an aquifer. In Marion County, the Powell is an independent aquifer in a few areas, but generally east of Marion and Searcy counties it cannot be distinguished on the drillers' lithologic logs from the underlying Cotter.

The Cotter and Jefferson City Dolomites, which are indistinguishable on the drillers' lithologic logs, make up the fourth major aquifer zone. This aquifer is the most widely utilized in the study area, especially where it is exposed in the northern portions of Baxter, Fulton, and Sharp counties. The wells range in yield from 1 to 50 gpm with a mean and median of 12.0 and 10.0 gpm, respectively. Depth of the wells range from 50 to 740 feet with a median and mean of 225

Table 1. Range, mean, and median of depth and yield of aquifers within the study area.

Aquifer	Depth (ft)			Yield (gpm)		
	Range	Median	Mean	Range	Median	Mean
St. Peter	35-113	85	80	1-20	5	9
Everton	80-812	500	338	1-40	7	11
Powell	43-275	114	137	7-40	15	18
Cotter-Jefferson City	50-746	225	264	1-50	10	12

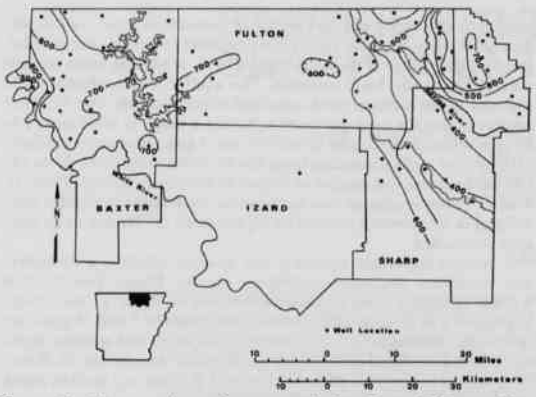

Figure 3. Piezometric surface map of the Cotter-Jefferson City Aquifer.

and 264 feet, respectively (Table 1). This aquifer generally is confined, but unconfined conditions occur locally.

A piezometric surface map was made for the Cotter-Jefferson City aquifer since 79 of the 109 plotted wells were within this aquifer (Fig. 3). Insufficient data exist for constructing piezometric surface maps of the other aquifers. The average hydraulic gradient for the aquifer is 9 ft/mile with water movement being generally southwest. The map indicates that aquifer discharge occurs along the White River in western Baxter County and along the Spring River in eastern Fulton and Sharp counties (Fig. 3).

STATISTICAL

The statistical relationships among well depth, regolith thickness, piezometric level, yield (gpm), and depth to the water table were determined from the hydrologic data compiled from drillers' well reports in the study area for the Cotter-Jefferson City aquifer. Comparisons were made using the Spearman Rank Correlation Coefficient (Siegel, 1956) and the aid of computer SAS (Barr et al., 1976) procedures.

Information was obtained from 177 drillers' reports. A comparison between yield and depth of well showed greater yield at shallow well depths at an $\alpha = 0.1$ significance level. A significant relationship at an $\alpha = 0.1$ probability also exists between yield and depth to the water table. Greater yield is found where the water table is closer to the surface. These correlations indicate the strong control on ground water movement by solutionally enlarged fractures at shallow depths in the aquifer and the tightening of fractures at depth due to greater lithostatic pressure. Thicker regolith was also found to be correlated with deeper wells and as the depth to water increases so does the regolith thickness. Although not statistically related, an inverse trend showing less yield among thicker regolith zones was found. These three trends suggest that there is not a significant difference in the thickness of regolith on or off fractures, but that regolith thickness is related to depth of weathering, which is a function of depth to the water table. Thicker regolith is found where it is deeper to the water table since weathering processes operate more effectively in the zone of aeration.

CONCLUSIONS

Four important aquifers of Ordovician age exist in Baxter, Fulton, Izard, and Sharp counties. From oldest to youngest they are: 1) the Cotter-Jefferson City Dolomite, 2) the Powell Dolomite, 3) the Everton Formation, and 4) the St. Peter Sandstone. The most productive aquifer is the Powell Dolomite, whereas the most widely utilized aquifer in the Cotter-Jefferson City due to its large surface exposure.

Statistical relationships at the $\alpha = 0.1$ significance level were found to exist between 1) yield and depth of well, 2) regolith thickness and depth of well, 3) yield and depth to the water table, and 4) regolith thickness and depth to water. These relationships strongly emphasize the importance of weathering by solution in enlarging fractures in carbonate rocks and thereby enhancing yield, but that the actual regolith thickness is more a function of depth of weathering which is more controlled by depth to water than fracture proximity.

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RELATION OF MAGNETIC AND GRAVITY FIELD DATA TO SELECTED STRUCTURAL ELEMENTS OF THE CENTRAL PORTION OF THE ARKOMA BASIN

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ABSTRACT

In order to acquire a greater understanding of some of the major basement structural features characteristic of the Arkoma basin, magnetic and gravity data have been collected and analyzed for a selected area. Several anomalies exist and are found to be associated with faulting or major fracturing in the Precambrian basement. Modelling of source bodies based on magnetic and gravity values provides quantitative estimates of the depth as well as the geometry of basement structural geology.

INTRODUCTION

The Arkoma basin is an arcuate, east-west trending structural trough bounded on the north by the Boston Mountain plateau and on the south by the Ouachita Mountain fold belt. Structural geology studies in the central portion of the Arkoma basin in Arkansas have dealt primarily with the mapping of surface structure as well as mechanical well log correlation of lenticular, gas-producing sandstone bodies of the Atoka Formation. Very little information has been published regarding the structural configuration of the Precambrian igneous basement. In order to provide an initial, quantitative view of some of the major structural elements of the igneous basement, ground magnetic and gravity field surveys have been conducted in a selected portion of the Arkoma basin of Arkansas.

LOCATION AND REGIONAL GEOLOGY

The area of study is located in the Arkansas River Valley and includes the southernmost part of the Boston Mountain plateau south of the Mulberry fault. Using the General Land Office Grid System the location is given as follows: townships 10, 11, north, ranges 25, 26, west; one additional township is included for magnetic field coverage: township 9, range 25 (see Fig. 1). Included are portions of Franklin and Johnson counties. The general topography of the land becomes gentler toward the Arkansas River but more rugged and dissected to the north.

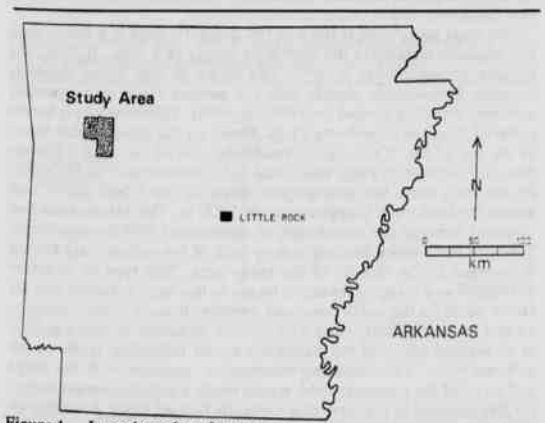

Figure 1. Location of study area.

In the vicinity of the study area, the Arkoma basin is bounded on the north by the northern Arkansas structural platform (Chinn and Konig, 1973). Among the prominent structural features of this platform is a pattern of northeast-trending lineaments which are visible on LANDSAT and RADAR imagery (Tolman, 1979). The Fayetteville and Drakes Creek faults are part of this pattern. These faults show a variable amount of vertical displacement along their trace (0-92 m) and are downthrown to the southeast. This variability in vertical displacement has been explained through movements related to solutioning of carbonate rock at depth (Quinn, 1973). The Arkoma basin was once part of the large Ouachita geosyncline, and is now one of seven structural basins that lie along the northern margin of the Ouachita Mountain System. Depths to basement increase southward to an estimated 9,200 m along the frontal zone of the mountains (Branan, 1968).

The Paleozoic carbonate section is composed of Cambrian through Pennsylvanian age limestone and dolomite. Sandstone and shale represent the principal lithologies of the Pennsylvanian System. The Pennsylvanian age Atoka Formation is by far the thickest unit in the study area and is composed of shale with subordinate amounts of siltstone and sandstone.

The common surface structures of the Arkoma basin include box-shaped synclines separated by narrow anticlines (Viele, 1973), regional monoclines, zones of normal faulting, and zones of imbricate thrust faulting (Diggs, 1961). In the study area, normal faulting is dominant over reverse faulting. Well records indicate that depths to basement increase in a southerly direction. Arkansas Western Gas Company penetrated the granitic basement at 7,467 ft below the surface in the Woolsey No. 1 well located in sec. 13, T.10N., R.27W., Franklin County. This location is less than a mile west of the study area.

Diggs (1961) concluded that the tectonic framework of the Arkoma basin represents the effects of tensional stress produced by the uplift of the northern Arkansas structural platform followed by the effects of compressional stress caused by the Ouachita orogeny on the south. The first emergence of the northern Arkansas structural platform occurred during the late Devonian. During the middle and late Pennsylvanian period subsidence accelerated, and the basin dropped rapidly along south-dipping normal faults (Viele, 1973).

GEOPHYSICAL SURVEYS AND DATA REDUCTION

The ground magnetic field survey was conducted by making observation stations at approximately one-mile intervals. Base stations

were established and periodically revisited in order to account for diurnal variation in the geomagnetic field. A total field measuring proton procession magnetometer, with a sensitivity of ±1 gamma was used throughout the study. A two-dimensional display of the total geomagnetic field was produced from the survey results and is shown in Fig. 2.

A gravity field survey was made in order that gravity data could be integrated with the magnetic field data to provide a more unique view. Stations for gravity measurements were spaced at an average of two miles, although some irregularity exists depending on the distribution of surveyed points of known elevation. Base stations were established and periodically rechecked in order to compute local tidal variations. A Worden gravity meter (Prospector Model) was used in conducting the survey.

For each gravity station reading a tidal drift, Free-air, Bouguer, latitude, and terrain correction was applied. A datum elevation of 92 m above sea level was selected for this investigation. The density of the assumed Bouguer slab was chosen to be 2.50 g/cc. The results of the calculations are replotted and the points contoured to produce a complete Bouguer gravity map (Fig. 3). In order to reduce the effect of the regional gravity field and enhance local anomalies, the complete Bouguer gravity field was continued downward one km (3,282 ft) below the surface. The downward continuation was done automatically using a FORTRAN computer program developed by Rudman and Blakely (1975) which is based on an algorithm presented by Henderson (1960).

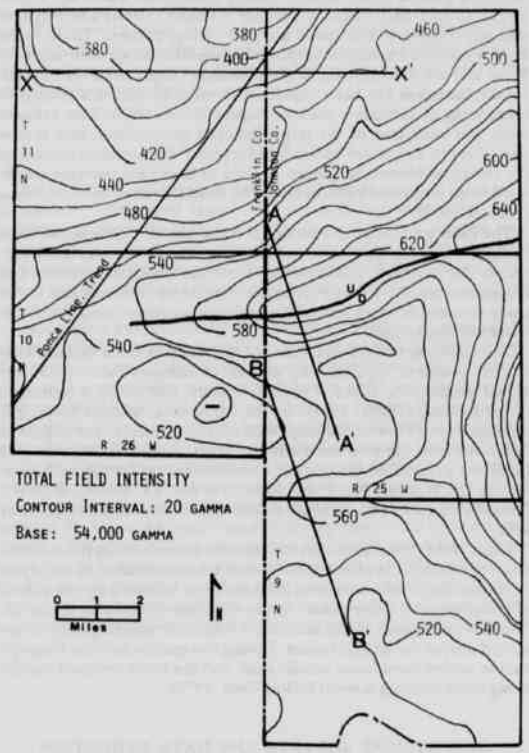

Figure 2. Total field magnetic intensity map showing location of cross sections and structural features.

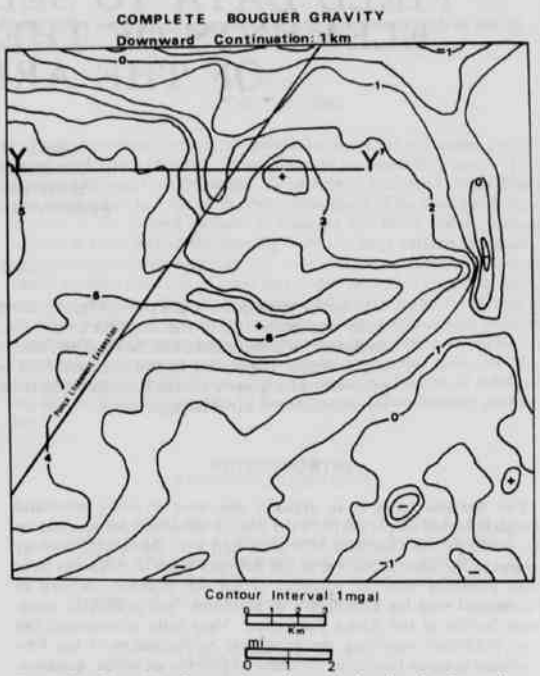

Figure 3. Complete Bouguer gravity map showing the Ponca lineament extension. Location given by T.10-11N., R.25-26W.

GEOLOGIC INTERPRETATION

In the study area and vicinity a deepening of the basin occurs to the south. This is evidenced by a general decrease in the amplitude of magnetic field anomalies and a corresponding decrease in the intensity of the magnetic field in the region immediately south of the study area (McBride, 1980). This is particularly noticeable in T.9N., R.25W. The sharp steepening of the magnetic field near the eastern boundary of T.10N., R.25W. is caused by the existence of a positive having a magnetic anomaly maximum which lies seven miles to the east (McBride, 1980).

The most prominent feature of the magnetic field is a linear positive anomaly situated in the northwest corner of T.10N., R.25W. and striking approximately N.70°E. The strike of this linear magnetic anomaly corresponds closely with the surface trace of a generally east-west trending normal fault (Haley, 1976). This structure is herein referred to as the Strawberry Fault. Based on the stratigraphic throw of the top of the "Cecil Spiro" sandstone unit of the Atoka Formation, the Strawberry Fault was found to be downthrown to the south. In the study area, the stratigraphic throw of the "Cecil Spiro" unit across the fault trace is approximately 1,230 m. This information was obtained through the correlation of mechanical well log signatures. Down-to-basin block faulting in deep beds of the sedimentary section is common in the vicinity of the study area. This type of structure developed as a result of tensional forces as the basin subsided and the Ozark uplift on the north remained positive (Branan, 1968). Buchanan and Johnson (1968), using well records, postulate as much as 1000 m of vertical offset of the basement across individual faults of the Arkoma basin. The preceding information, together with the shape and trend of the magnetic field, would imply a suprabasement source for this anomaly in the form of a vertically faulted block downthrown

to the south. Since the magnetic susceptibility of the local sedimentary section is negligible relative to igneous rock, the configuration of the magnetic field is nearly independent of material overlying the basement.

The method of direct interpretation used for the Strawberry fault anomaly was developed by Qureshi and Nalaye (1978) and is based on a vertical block fault. Following Koulomzine et al. (1970), the origin is found analytically by locating conjugate points on the field curve after which the symmetrical and asymmetrical components are analyzed separately. In this way the source can be identified and the geometry of the block determined.

In Fig. 4 the magnetic field is displayed along the section A-A'. Based on the above interpretation procedure, the depth to the block apex was found to be 1,070 m and the vertical displacement of the igneous basement 670 m. The magnetic anomaly profile, oriented perpendicular to the face of a horizontal step (Grant and West, 1965) with the above dimensions, is shown in Figure 4 for comparison. The magnetic susceptibility associated with the theoretical anomaly is 0.0020 emu which is close to the average figure for granitic rock (Dobrin, 1976). This value then gives an estimate for the magnetic susceptibility of the igneous basement. A problem arises as to the explanation of a basement fault having less displacement (670 m) than the overlying Strawberry fault (1,230 m). That the Precambrian igneous basement fault coincides with the Strawberry fault in the sedimentary section indicates basement faulting was important in controlling faulting in the overlying sediments. However, the fact that the vertical displacement in the basement is much less than the throw in the upper part of the Atoka Formation is interpreted to imply that basement faulting did not completely control development of the Strawberry fault in the sedimentary section.

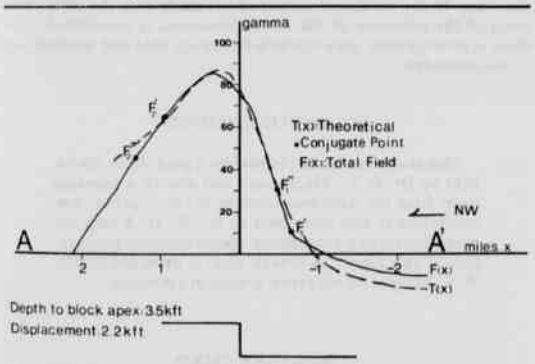

Figure 4. Profile A-A' (see Figure 2) comparing observed and theoretical magnetic field anomalies associated with a fault.

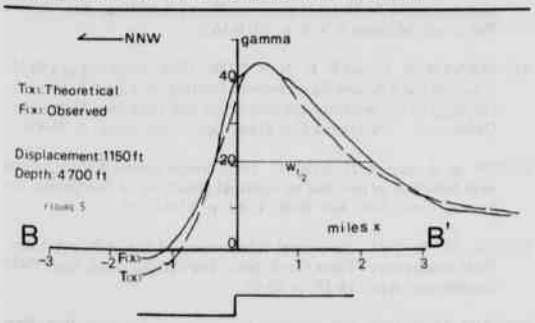

Figure 5. Profile B-B' (see Figure 2) comparing observed and theoretical magnetic field anomalies associated with a fault.

Another positive, linear magnetic anomaly exists near the south of T.10N., R.25W. which is much less in magnitude than the Strawberry fault anomaly but similar in shape. The strike of the anomaly is approximately equal to that of the Strawberry fault anomaly to the north, N.70°E. These two linear highs are separated by a trough-like, anomalous low in the magnetic field. The minimum value of total magnetic intensity in this area is less than 54,500 gamma. The configuration of the magnetic field here suggests a model based on a vertical basement fault downthrown to the north. We examine a profile along the line B-B'.

Grant and West (1965) give a simple method of interpretation based on a thin horizontal step. This method uses a technique of measuring certain characteristic estimators from the total field anomaly from which are obtained values for the geometrical parameters involved. These estimates are the half-width and the amplitude of the field curve. In this example estimations were obtained and the corresponding theoretical magnetic anomaly curve plotted for comparison and revision based on a magnetic susceptibility of 0.0020 emu. The results of the curve superposition are shown in Fig. 5. Based on this work the depth of the top of the upthrown block on the south is 1,450 m and the vertical displacement 340 m. No corresponding fault having a similar orientation has been found to exist on the surface (Merewether and Haley, 1969).

The orientation of two thusly described basement block faults, having parallel strikes, implies the existence of a basement graben structure. Such a structure would have evolved as a result of tensional forces associated with the Ozark uplift and Arkoma basin subsidence.

The final area to be discussed involves the influence of major northeast-trending lineaments visible on small scale imagery on the earth's magnetic and gravity fields. The Ponca lineament strikes subparallel to the Fayetteville fault and Drakes Creek fault lineaments and can be traced on satellite imagery a minimum distance of 81 km (Smith, 1977). The Ponca lineament trend direction intersects the northwest section of the study area (see Figs. 2 and 3). The Mulberry fault strikes generally east-west and exists less than two miles north of the study area. South of the Mulberry fault the Ponca lineament does not readily appear as a topographically defined feature on satellite imagery. From this situation a controversy immediately arises concerning the geologic significance of "extending" the Ponca lineament southward into the Arkansas Valley where it seems to disappear.

In order to define the physical and geologic character of the Ponca lineament, Smith (1977) developed a series of east-west magnetic and gravity field profiles across the Ponca lineament in the vicinity of Ponca, Newton County, Arkansas. It was found that to the west of the Ponca lineament a minimum in the vertical component of the magnetic field consistently appears. The magnitude of these minima is approximately 75 gamma. The complete Bouguer gravity data show a well-developed minimum having a magnitude of three mgal coinciding with the trace of the Ponca lineament. This gravity low is probably related to a negative density contrast produced by a vertical zone of fractured rock. Based on the geophysical data, Smith (1977) concluded that the Ponca lineament is associated with a low density fracture and/or shear zone developed parallel to the lineament and penetrating the Precambrian basement as well as the overlying Paleozoic sedimentary section. It is also postulated that no vertical displacement on the basement has occurred.

In the northwest corner of the present study area a pronounced low in the magnetic field develops just to the west of the Ponca lineament trend direction (see Fig. 2). Profile X-X' (Fig. 6) shows the total magnetic field on the surface and continued downward one km in an east-west direction, intersecting the lineament trend direction. At a continuation downward of one km a minimum centers about the lineament direction. Also the displacement of the total magnetic field at this level is now approximately 100 gamma. This is comparable to the anomaly magnitude in the vicinity of Ponca, Arkansas. A downward continuation of one km is equivalent to a field observed roughly 780 m above the basement which is close to the basement depth near Ponca, Arkansas. The general configuration of the magnetic field near the lineament trend in the study area, together with the dis-

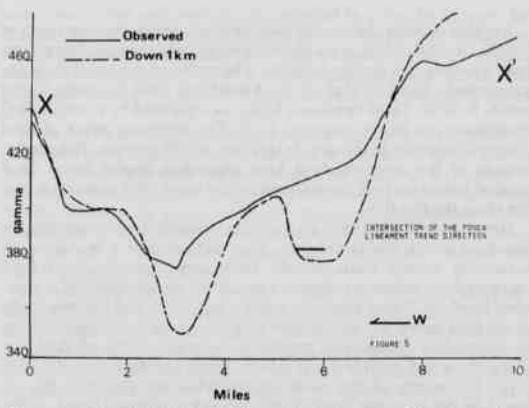

Figure 6. Profile X-X′ (see Figure 2). Influence of the Ponca lineament on the surface magnetic field and its downward continuation.

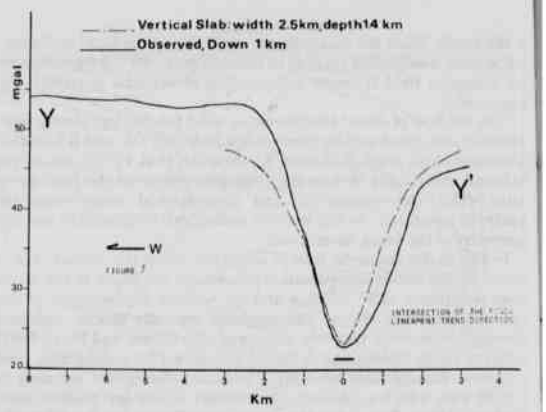

Figure 7. Profile Y-Y′ (see Figure 3) comparing observed and theoretical anomalies over the Ponca lineament.

cussed similarities suggests that the Ponca lineament has an associated fracture zone south of where it diminishes at the Mulberry fault.

In order to examine this problem more closely, a complete Bouguer gravity map (Fig. 3) has been prepared. The gravity field has been continued downward one km so as to enhance local anomalies and subdue the regional field. On this map the Ponca lineament trend direction is also indicated and coincides with a trough-like low in the gravity field of magnitude approximately three mgal. This is the same value given by Smith (1977) for the Ponca, Arkansas area. Fig. 7 gives the gravity anomaly across the direction along the profiles Y-Y′. Assuming a low density vertical slab (Nettleton, 1976) to represent a vertical fracture or shear zone, a comparison of the observed field with a theoretical field is used (Fig. 7). Based on this comparison, it is concluded that the fracture zone initiates at a depth of 1.4 km (4,594 ft) and has a width of 2.5 km (1.55 miles). A density contrast of 0.04 g/cc is required to achieve these figures. A depth of 1.4 km places the top of the low density vertical slab above the surface of the Precambrian basement but within the Cambrian-Ordovician dolomite. Assuming fracturing has occurred, a density contrast of 0.04 g/cc in rock ranging 2.65-2.75 g/cc in density (i.e., granite and dolomite) would yield a fracture porosity of 1.5%. Schumacher (1979) reported on the results of a gravity study of an area in the Arkoma basin which included the Drakes Creek fault lineament. In this study, it was concluded that the Drakes Creek fault lineament is associated with a low density fracture zone having dimensions similar to those derived for the Ponca lineament fracture zone. Based on the foregoing discussion it is then concluded that the Ponca lineament has an associated structure trending in the same direction and represented by a low density fracture or shear zone with no vertical displacement. This fracture zone exists in the Precambrian basement and possibly in the lower Paleozoic sedimentary section.

CONCLUSIONS

The magnetic and gravity methods of subsurface investigation are useful in refining existing knowledge of the structural elements within the Arkoma basin. The southward sloping basement surface is interupted by east-west trending faults. The Strawberry fault is a normal fault in the overlying sediments and is downthrown to the south with a significant amount of throw. This fault corresponds to an elongated magnetic anomaly which is related to a basement block fault downthrown to the south. This basement block fault is genetically related to the overlying Strawberry fault. However, displacement on the basement fault is significantly less than the throw on the associated Strawberry fault. South of the Strawberry fault area there exists an anomalous low in the magnetic field terminated on the south by a second, but lesser elongated magnetic anomaly. This anomaly is also related to a basement block fault but in this case downthrown to the north. This arrangement of basement faults produces a graben-like structure. In the northwest corner of the study area the subsurface trend of the extension of the Ponca lineament is established. This trend is substantiated quantitatively by gravity data and qualitatively by magnetic data.

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STRATIGRAPHIC RELATIONSHIPS OF THE BRENTWOOD AND WOOLSEY MEMBERS, BLOYD FORMATION (TYPE MORROWAN), NORTHWESTERN ARKANSAS

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ABSTRACT

The Brentwood Member of the Bloyd Formation conformably overlies the Prairie Grove Member, Hale Formation in the type Morrowan succession of northwestern Arkansas. At its type locality, the Brentwood is separated from the underlying Prairie Grove Member by nearly 6 m of dark shale. Away from this area, the shale thins rapidly and the Hale-Bloyd boundary may be placed with difficulty. At some localities east of type section, the boundary is thought to be erosional rather than the more typical gradational contact. The Brentwood consists of discrete carbonate bodies separated by dark shales. The carbonates consist principally of open shelf deposits, such as crinozoan biosparites and oolites. All carbonate lithologies contain varying amounts of fine to medium grained, rounded, quartz sand. Regionally, the Brentwood Member becomes more shaly to the west of its type locality and loses the quartz sand content in its carbonate lithologies. To the east, the Brentwood shales become less prominent and quartz sandstone intervals characterize the succession.

The Woolsey Member overlies the Brentwood Member and consists of light to dark, argillaceous shales with occasional sandstones, carbonates, and a thin coal. The coal is confined essentially to Washington and northern Crawford counties and never exceeds 45.7 cm. The shales are thought to be of terrestrial origin, but marine fossils and thin limestones in the lower part of typical Woolsey strata indicate a transitional change within the member rather than at its base. In contrast, the detrital fraction of the upper Brentwood carbonates seem to decrease rather than increase towards the Woolsey contact. To the west of the type area, the Woolsey gives rise to marine shales and carbonates. To the east, the Woolsey is equivalent to a thick, quartz pebble-bearing sandstone of fluvial origin. The top of the Woolsey Member is a regional unconformity with the overlying Dye Shale Member, Bloyd Formation.

INTRODUCTION

Lower Pennsylvanian (Morrowan) strata of northwestern Arkansas may be characterized as a succession of predominantly marine shales, sandstones, and occasional limestones. In addition, a terrestrial horizon with an associated coal seam is also developed in the type Morrowan Series. The succession has been divided into the Hale and overlying Bloyd Formations. The Hale Formation has been subdivided into the Cane Hill Member (basal) and the Prairie Grove Member. The Bloyd Formation has been subdivided into four members. These are (ascending order) the Brentwood, Woolsey, Dye, and Kessler Members (Henbest, 1962; Sutherland and Grayson, 1978). This report deals with the lithostratigraphy of the Brentwood-Woolsey interval, Bloyd Formation, in its type region.

LITHOSTRATIGRAPHY

Brentwood Member: Strata referred to the Brentwood Member, Bloyd Formation were originally referred to the Pentremital Limestone of the Boston Group (Owen, 1858; Simonds, 1891). Adams and Ulrich (1904) abandoned the name Pentremital Limestone in favor of the name Brentwood to designate this member of the Morrow Formation. No type section was proposed at that time, although the term Brentwood was stated to be derived from exposures near Brentwood station in northwest Arkansas (Adams and Ulrich, 1905). The name Morrow Formation was raised to group status by Purdue (1907). He proposed the Bloyd Shale to include the Brentwood Limestone Member of Adams and Ulrich (1904) and the Kessler Limestone Member of Simonds (1891). The name Bloyd was derived from exposures on Bloyd Mountain northwest Arkansas. Purdue (1907) also raised the Hale sandstone lentil of Taff (1905) to formation status. As a result, the Morrow Group included the Bloyd Shale and underlying Hale Formation with the Brentwood and Kessler Limestones as formally named members of the Bloyd Shale. No type section was designated for either the Hale Sandstone or Bloyd Shale. This use of the Hale and Bloyd remained essentially unchanged for four decades.

Henbest (1953) designated a type section for the Brentwood Limestone on the east side of both U.S. Highway 71 and the west fork of the White River, approximately a half mile south of Mill Creek. This section is located in the center of the N. Sec. 16, T. 14 N., R. 30 W., Washington County, Arkansas. Henbest (1962) designated a type section for the Bloyd Shale on the southwest part of Bloyd Mountain extending from the center of the E. Sec. 3 to the center, north side of sec. 4, T. 14 N., R. 30 W., Washington County, Arkansas.

The Brentwood Member, in its type region, may be described as a succession of quartz-bearing limestones and shales that accumulated under shallow-shelf conditions. The member ranges in thickness from 9 to 24 m in outcrop and thickens to 31 m or more in the subsurface to the south and southwest. The discrete limestone intervals average less than 1.5 m. A single section may contain from two to five carbonate units separated by dark-gray to black, fissile shale. The shale is generally non-silty and non-calcareous. The limestones are bioclastic grainstones and packstones which may contain calcareous sandstone lenses which display low angle, trough cross stratification.

The basal contact of the Brentwood, as defined by Henbest (1953), is conformable with the underlying Prairie Grove Member, Hale Formation. The boundary is drawn below the first shale bed, 0.5 m or more in thickness, above the Prairie Grove Member. The Prairie Grove varies in lithology from sandy carbonates to calcareous sandstones, but is essentially shale free throughout northwest Arkansas. The contact is distinctive at the type section of the Brentwood, where

the basal shale averages 5.5 to 6 m in thickness. Placement of the Brentwood-Prairie Grove contact becomes confused away from central Washington County due to thinning of the basal shale (Fig. 1A). The nature of the contact remains transitional to the west of the type area. At many localities, more than one shale horizon may be present in proximity to the boundary. These shales average less than the 0.6 m minimum thickness defined by Henbest (1953). Since the Prairie Grove Member is mapped as a shale-free unit, the Prairie Grove-Brentwood contact is drawn below the first occurrence of shale above the last Prairie Grove lithology regardless of the thickness of that shale.

East of the type area, the basal shale thins rapidly, becoming absent throughout a large portion of northwest and northcentral Arkansas. In areas where the basal shale cannot be used as a marker, the Prairie Grove-Brentwood contact is drawn between the last massive, persistent, bluff-forming calcareous sand of the Prairie Grove and the dark calcarenites of the basal Brentwood Member. Upper Prairie Grove sands typically exhibit a characteristic honeycomb weathering pattern that is related to cementation. Pockets of calcareous cement are scattered throughout the unit that is elsewhere cemented by iron oxide. Upon exposure, these pockets are solutioned more rapidly than the iron oxide cemented areas resulting in the pitted appearance of the weathered surfaces. The contact tends to be erosional and sharp, rather than gradational, in areas where the basal shale is absent. The erosional nature is suggested by truncation of upper Prairie Grove beds by carbonates of the basal Brentwood Member. The *Neognathodus symmetricus* Zone spans the contact indicating little time significance to the hiatus (Lane, 1977).

The Brentwood Limestone forms a broad belt trending northeast-southwest through Washington, Crawford, Madison, Newton, Carroll, and Boone counties, Arkansas (Fig. 1B). South of this area, the unit gently dips into the subsurface; it is truncated to the north. Different nomenclature is utilized for most of the Morrow interval, including the Brentwood, to the east and west of the type region due to pronounced facies changes. In northcentral Arkansas, the sand content of the Prairie Grove Member, Hale Formation and the whole of the Bloyd Formation increases to such an extent that they are combined as the Witts Springs Sandstone (Glick et al., 1964). Brentwood equivalents are included with the Braggs Member of the Sausbee Formation in eastern Oklahoma (Sutherland and Henry, 1977).

Woolsey Member: The Woolsey Member overlies the Brentwood Member in northwest Arkansas. It was named by Henbest (1953) for exposures near Woolsey Station, Arkansas. Until that time, informally it had been referred to as the coal-bearing shale. D. D. Owen (1858) was the first to describe this unit, but no type locality was defined. Simonds (1891) included the coal-bearing shale in his description of the Boston Group. Later, it was included in the Morrow Formation of Adams and Ulrich (1904), and finally the Bloyd Shale by Purdue (1907). The coal bed associated with the Woolsey Member was named the Baldwin Coal by Croneis (1930) for exposures at Baldwin Station, Washington County. Henbest (1962) defined the type section of the Woolsey as the south and west side of Bloyd Mountain from the center, E ½ Sec. 3 to the center, north side, Sec. 4, T. 14 N., R. 30 W., Washington County, Arkansas.

The Woolsey Member is essentially restricted to a northeast-southwest belt through Washington and Crawford counties, Arkansas (Fig. 1C). It dips into the subsurface to the south, and it is truncated to the north and east. Woolsey equivalents are incorporated into the Brewer Bend Limestone Member of the Sausbee Formation in northeastern Oklahoma (Sutherland and Henry, 1977).

Following deposition of the Brentwood Member, the Morrowan seas regressed to the southwest trailed by near-shore fresh water marsh environments. The majority of the sediments, which compose the Woolsey, were deposited in these marsh environments. Dark-gray, fissile shale comprises the thicker intervals of the succession. Plant impressions are found sporadically on the shale partings. In addition, thin intervals of siltstones are interbedded with Woolsey shales. The siltstones are generally thin bedded and display ripple bed forms. The coal seam, where present, varies from 2.5 to 45.7 cm in thickness (Fig. 1C). It occurs in a variety of positions with respect to the marine caprock at the base of the overlying Dye Shale Member. No systematic, predictable occurrence of the coal seam has been recognized. The Woolsey ranges from 3.2 to 31 m in outcrop, and thickens to 33 m or more in the subsurface (Fig. 1C). The thickening of the shale sequence in a down slope direction during the time of deposition suggests the possibility of a marine component to the basal Woolsey to the south.

The contact between the Brentwood and Woolsey members, Bloyd Formation, as defined by Henbest (1953), is unconformable. Placement of the contact in outcrop is confused by the similarity of marine and terrestrial shales. Stratigraphic practice has been to place the contact at the highest carbonate horizon found in the Brentwood. At many localities, a conglomerate is preserved at this horizon indicating both an unconformable contact and a change to non-marine deposition. At other localities, a thick shale sequence, probably grading from marine to non-marine, occurs above the highest limestone of the Brentwood. The Brentwood Woolsey contact in a depositional sense must fall within this interval, but it is placed at the top of the last limestone because of mappability and difficulty with determination of environmental change.

East of the Washington-Madison County Line, the Woolsey interval is represented by an unnamed middle Bloyd sandstone. This sandstone unconformably overlies the Brentwood Member throughout much of northwest and northcentral Arkansas. The sands, which compose the middle Bloyd sandstone, were deposited under largely fluvial conditions coeval with the Woolsey marshes during the regression of the Morrowan seas. Marine transgression, represented by the basal conglomerate of the Dye Shale, terminated Woolsey deposition throughout northern Arkansas.

CONCLUSIONS

The contact between the Brentwood Member and the underlying Prairie Grove Member, Hale Formation is conformable and drawn below the first occurrence of shale 0.6 m or more in thickness above the Prairie Grove. Placement of this contact becomes confused away from central Washington County due to variations in thickness of the basal shale. Stratigraphic practice has been to map the Prairie Grove Member as a shale-free unit. As a result, the first occurrence of shale regardless of its thickness is commonly used to mark the Prairie Grove-Brentwood contact. In areas where the shale cannot be used as a marker, the Prairie Grove-Brentwood contact is drawn between the last massive, calcareous sand exhibiting a honeycombed weathering pattern (Prairie Grove) and the first dark calcarenite (Brentwood Member).

The Woolsey Member is a succession of terrestrial siltstones and shales which unconformably overlie the Brentwood Member. Stratigraphic practice has been to place the Brentwood-Woolsey contact at the highest carbonate horizon found in the Brentwood. The difficulty in distinguishing between marine and terrestrial shales in the field makes this a practical contact, although the actual depositional change may occur within the shales above the highest carbonates. The Woolsey Member is a lateral equivalent of an unnamed Middle Bloyd sandstone which unconformably overlies the Brentwood Limestone throughout most of northwest and northcentral Arkansas east of the Washington-Madison County Line.

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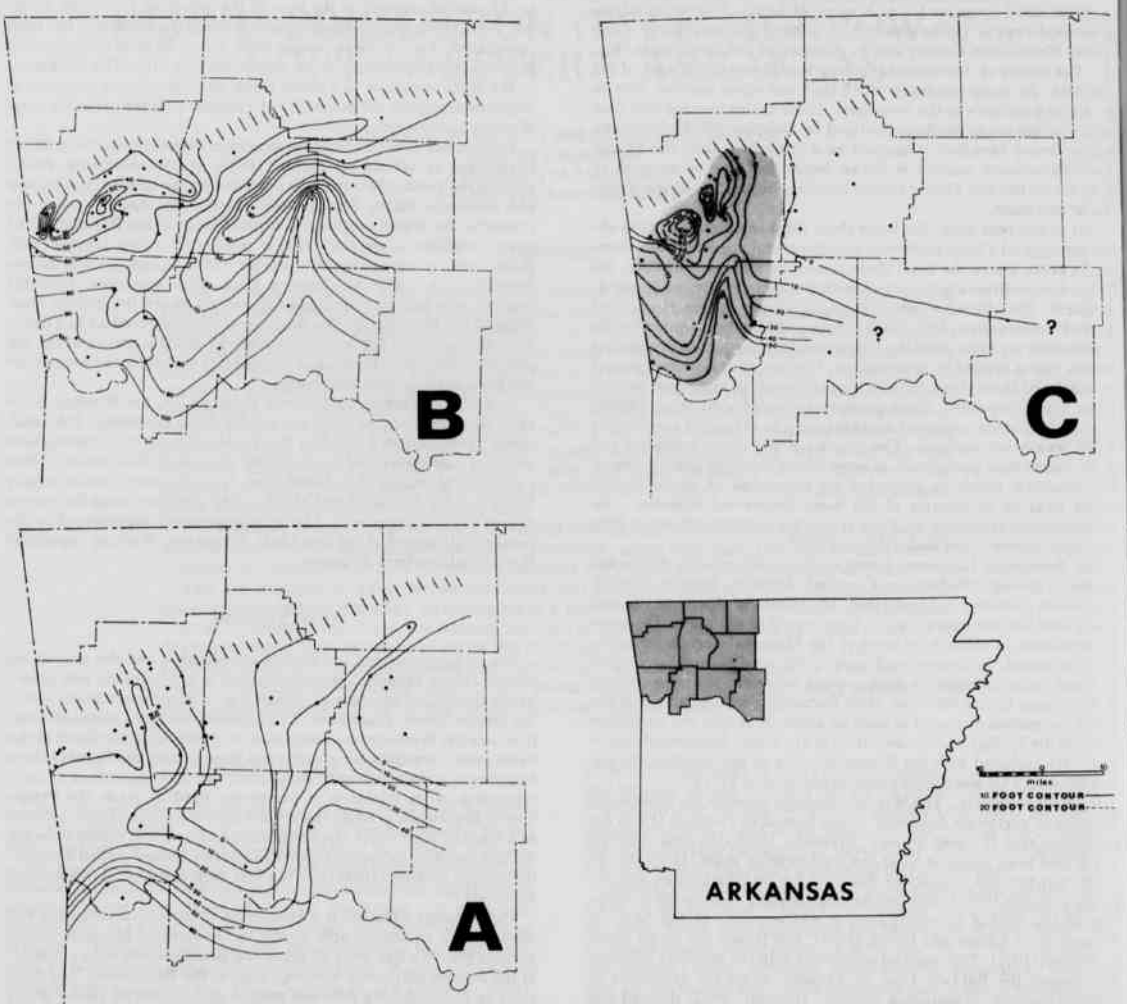

Figure 1. Regional Distribution of Brentwood-Woolsey strata, northwest Arkansas. A—isopachous maps of basal Bloyd Shale; B—isopachous map of total Brentwood Member including basal shale; C—isopachous map of total Woolsey Member with coal distribution shown by stipple pattern.

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EVALUATION OF A FULL-FAT SOYBEAN RATION FOR CHANNEL CATFISH PRODUCTION IN CAGES*

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ABSTRACT

An experimental ration consisting of 50% full-fat soybeans, heated 170°C, was compared to a commercial trout chow in a 120-day feeding trial using two stocks of channel catfish, *Ictalurus punctatus* Rafinesque. Catfish were reared in 0.9 m^3 floating cages, with 200 fish per cage, anchored in a 1.5 hectare farm pond. A Central Arkansas stock significantly outperformed a Southeast Arkansas stock for comparisons of net production and food conversion efficiency (FCE), with 92% greater production and 41% better FCE, respectively. Survival was 90% or greater for all fish. There was no significant difference in dress-out weight between the stocks. However, the catfish fed the trout ration had significantly lower amounts of body fat. The commercial trout chow overall was significantly better for fish production than the full-fat soybean ration. Production with trout chow was 84% greater than with the full-fat soybean ration. Food conversion efficiency was nearly 41% better with the trout ration, while percent body fat was 11% less. There were no differences in percent survival and percent dress-out weight between the rations. The Central Arkansas stock fed the commercial trout ration had the lowest production cost of 0.47¢ per 0.45 kg live weight, while the Southeastern stock had a higher production cost with either feed.

INTRODUCTION

Cage culture of fishes has been practiced in Asia since the early part of this century (Hickling, 1962), but it has been during the past six-eight years that intensive cage culture operations have become feasible for channel catfish (Kilambi et al., 1977; Newton and Merkowsky, 1977). This has been due largely to the development of high protein, nutritionally complete diets. Caged catfish culture ration studies have been conducted at UAPB since 1975 (Newton and Merkowsky, 1976). Most diets for caged catfish culture have consisted of high percentages of animal proteins with little utilization of vegetable proteins. High percentages of animal proteins increase production costs of complete rations. In an attempt to reduce protein ingredient costs, researchers have attempted to substitute vegetable proteins for some of the animal proteins. Soybeans has been one of the major substitutes considered in reducing the amount of animal proteins. The chemical composition of soybeans and their amino acid profile rank them as one of the better plant products for consideration in fish diets. However, soybeans that are not heat-treated are not completely utilized by monogastric animals (Smith, 1977). Brandt (1979) determined that heat treating soybeans to 170°C destroyed growth inhibitors (hemagglutinins, goitrogens, protease inhibitors). His studies at the Stuttgart Fish Farming Experimental Station have indicated that in pond culture, properly heat-treated soybeans in a balanced diet provided good growth, production, and survival for channel catfish.

The objectives of this study were (1) to assess the performance of caged channel catfish fed a 50% full-fat heat-treated soybean ration, and (2) to compare two catfish stocks' performance fed the soybean ration and a commercial trout ration.

METHODS AND MATERIALS

Catfish fingerlings were obtained from Central and Southeast Arkansas representing two stocks of channel catfish. Floating cages (0.9 m^3) were anchored in a 1.5 hectare farm pond at the UAPB Agriculture Experiment Station (Newton and Merkowsky, 1976). Fingerlings were stocked at the rate of seven fish per 28.3 dm^3 (200 fish per cage). Each stock of catfish was fed both the commercial trout ration (TC - 36% protein) and a 50% full-fat soybean ration (FFS - 36% protein) formulated by Brandt *(pers. comm.)*. Experimental conditions were triplicated for fish stocks and rations. The 50% full-fat soybean ration was prepared by the Kansas State University Department of Grain Science and Industry, Manhattan, under the supervision of Dr. Keith Behnke. The experimental ration formula is on file in the UAPB Fisheries Library.

Fish were placed in the cages and preconditioned for five days before the experiment was initiated 24 April 1979. The catfish were fed six days per week for a total of 120 feeding days. All fish were fed 3% of their estimated body weight according to a schedule that was adjusted bimonthly based upon a 1.5:1 feed conversion ratio. Periodic samples were taken of at least 10% of the population to check for growth and to adjust the feeding schedule.

On 19 September, all fish were harvested and the total number and total weight were recorded for each cage. A 10% random sample of the fish was used to determine dress-out percentage, the portion of a fish available for market sale, and percent body fat, mesenteric fat of individual fish.

Both rations were tested for physical characteristics of size, number, percent moisture, and floatability. Average number of pellets per ten grams and average sizes were determined from ten samples of each ration. Percent moisture was determined from three samples of each ration with a Blue M drying oven at 100°C for 48 hr. Floatability was tested in a 75 l aquarium. A 300 pellet sample of each ration was placed in the aquarium with a water temperature of 27.6°C and observed for two hours. The pellets were then checked at the end of 24 hr and floating pellets counted. Significant differences among net production, survival, percent dress-out, percent body fat, physical characteristics of the feed, and average weight of the fish were tested by factorial analysis (Steel and Torrie, 1960). All statistical tests were compared at the 0.05 level of significance.

RESULTS AND DISCUSSION

There were no significant differences among the mean diameter pellet size (9.5 mm), percent moisture (9.9), or floatability (99%) between the two rations. However, there was a significant difference in the number of pellets per sample (TC:FFS = 1:1.5). The full-fat soybean pellets were 34% bulkier. Lovell (1977) noted that a bulky ration may be disadvantageous for good channel catfish growth. Thus decrease in growth may be accounted for because the catfish do not consume enough feed to meet their nutritional requirements. It was

*Published with the approval of the Director of the Arkansas Agriculture Experiment Station.

observed that the caged catfish routinely consumed all pellets within 20 minutes after feeding.

The Central Arkansas stock, compared to the Southeastern stock, had a significantly higher average net production and food conversion efficiency for both rations (Table 1). The Central Arkansas stock had a 92% greater net production than the Southeastern stock when fed the trout ration, and a 99% greater net production when fed the full-fat soybean ration. Comparisons between feeds revealed that both stocks had 84% increased production with the trout ration than with the soybean ration.

There was no significant difference in survival between the two stocks for either ration. The Central Arkansas stock produced a larger average-sized fish with either ration (Table 1). The trout ration produced the better average weight gain for both stocks.

There was no significant difference in the percent dress-out weight between the two stocks; however, there was a significant difference in the amount of mesenteric fat in the body cavity of the fish between the two feeds (Table 2). Catfish fed the trout ration had 11% less mesentric fat. Brandt (1979) found that catfish, in open ponds, fed a 50% full-fat soybean ration had a body fat percentage of 2.93. That amount of fat was significantly lower than our average of 5.67%. Some of the difference may be due either to the culture methods or to the heat processing of the full-fat soybeans.

A cost analysis (Table 3) indicated that the Central Arkansas stock fed the commercial trout ration was the better caged catfish/ration combination. Only marginal profit was obtained with the Central Arkansas stock fed the soybean ration. Net losses occurred for the Southeastern stock with both rations. Total cost to produce 0.45 kg of flesh ranged from a low of 47 cents for the Central Arkansas stock fed trout chow to a high of 90 cents for the Southeastern stock fed the full-fat soybean ration.

Overall comparisons, indeed, indicated that the trout ration was better for production of channel catfish in cages. Poor fish performance with the full-fat soybean ration could have been due to improper heat treatment of the raw soybeans. Improper heat treatment of soybeans would prevent adequate fish utilization of essential proteins and vitamins (Brandt, 1979). This may account for the poor performance of both catfish stocks with the full-fat soybean ration in cages as compared to previous feeding trials in open ponds. Further research may aid in establishing better quality control during soybean heat treatment processing. In addition, research needs to be conducted to further define the value of utilizing full-fat soybeans as a primary substitute for animal proteins in channel catfish rations.

The large significant difference in production performance between the two catfish stocks was puzzling. Broussard (1979) noted that wild strains of catfish did not perform as well as more domesticated strains in ponds or cages. The "wilder" the stock, the poorer the production in confined culture. The Southeastern stock appears to be a "wilder" stock than the Central Arkansas stock because of differences in cultural practices, management techniques, and total time of domestication. The Southeastern stock has been maintained by open-pond spawning with minimal selective breeding management. Also, that stock has undergone domestication over a relatively shorter time period. The Central Arkansas stock has been domesticated for a longer period and subjected to intensive cultural management practices (hatchery spawning, selective breeding, etc.).

Table 1. Survival, average net production, F.C.E., and individual gains for two channel catfish stocks fed two rations.

Stock	Ration	Average net production per cage (kg)	F.C.E.	Percent survival	Average fish weight (g) Initial	Harvest	Net gain (g)
Central Arkansas	TC	60.57 a [1/]	1.90 a	80 a	28 a	422 a	394 a
	FFS	30.25 b	2.50 b	90 a	28 a	240 b	212 b
Southeastern Arkansas	TC	36.27 c	2.68 c	95 a	28 a	200 c	172 c
	FFS	19.25 d	4.74 d	82 a	28 a	136 d	108 d

[1/]Means followed by different letters are significantly different at the 0.05 level.

Table 2. Comparison of marketable qualities between two catfish stocks fed a full-fat soybean and trout ration.

Stock	Ration	Percent body fat	Percent dress out weight
Central Arkansas	TC	4.05 a [1/]	60.39 a
	FFS	5.98 b	53.37 a
Southeastern Arkansas	TC	5.44 a	57.87 a
	FFS	5.57 b	54.68 a

[1/]Means followed by different letters are significantly different at the 0.05 level.

Table 3. Cost analysis on a per cage basis for two stocks of channel catfish.

Stock	Ration	Feed cost per kg	Fingerling cost	Harvest price per kg	Weight harvested (kg)	Ration cost	Net profit
Central Arkansas	TC	$0.55	$12.00	$1.43	75.09	$71.80	$21.57
	FFS	$0.42	$12.00	$1.43	43.75	$46.94	$ 1.57
Southeastern Arkansas	TC	$0.55	$12.00	$1.43	37.99	$32.02	-$ 3.67
	FFS	$0.42	$12.00	$1.43	17.35	$36.17	-$15.64

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HOW WE LOOK: STUDIES OF OCULOMOTOR-SYSTEM NEURAL CONNECTIONS

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ABSTRACT

The neural connections of the reticular formation (RF) with the vestibular nuclei (8V) and the ascending medial longitudinal fasciculus (MLF) were studied, because many neurons in these structures carry eye-movement and head-movement (vestibular) signals and are only one or two synaptic connections removed from eye motorneurons. We used stimulating electrodes placed in specific brainstem structures and a single-neuron recording microelectrode in anesthetized or decerebrate cats. Connections were determined when the neurons were excited either forwards (orthodromically) or backwards (antidromically) by a shock. Four classes of neurons were studied. One neuronal class in the pontine RF projects axons into the ascending ipsilateral MLF; these axons terminate in the midbrain. Some of these cells receive excitation from both vestibular nerves and are probably involved in the vestibulo-ocular reflex. Another class of RF neurons projects to either the ipsilateral or the contralateral 8V. A third class located amidst lateral-rectus motorneurons in the VIth nucleus projects into the contralateral ascending MLF and excites medial-rectus motorneurons for the contralateral eye so that the two eyes move horizontally in the same direction. A fourth class located in and just beneath the 8V receives monosynaptic input from the vestibular nerve and projects into the contralateral MLF. The possible roles for these neurons in controlling eye movements are discussed.

Abbreviations: MLF: medial longitudinal fasciculus; RF: reticular formation; 3: oculomotor (IIIrd cranial nerve) nucleus; 4: trochlear (IVth cranial nerve) nucleus; 6: abducens (VIth cranial nerve) nucleus; 8V: vestibular nuclear complex of the VIIIth cranial nerve.

INTRODUCTION

The oculomotor system is one of nature's most sophisticated control systems. It functions in the fixation of gaze upon visual objects and in the maintenance of steady retinal images during head and target movements. It thus beautifully complements and augments the capabilities of the visual system. There are five types of eye movements: fast, tracking, convergence upon near objects, image stabilization during movements of the visual surroundings, and image stabilization during head movements (vestibulo-ocular reflexes). We mainly will discuss the anatomical substrates for the last type, image stabilization during head movements. Motorneurons from the VIth cranial nerve nucleus (Fig. 1) control the lateral rectus muscle of the eye, motorneurons from the IVth nucleus control the superior rectus muscle, and motorneurons from the IIIrd nucleus control the other four extraocular muscles. Head rotations about all three axes of rotation are sensed by the semicircular canals, and head linear movements in all the three dimensions by the macula and saccule; the canals, macula and saccule are contained within the labyrinth (vestibule) of the inner ear. The vestibular signals travel along the VIIIth nerve to the 8V, a complex of four major and several minor clusters of neurons. The simplest pathway of a vestibulo-ocular reflex involves only one interneuron whose cell body is in the 8V. There are several projection varieties of this interneuron: ipsilateral or contralateral, excitatory or inhibitory axons to the IIIrd, IVth and VIth nuclei (Brodal, 1974; Cohen, 1974); some of these axons ascend within the fiber bundle called the MLF. Thus many MLF fibers originate in 8V. These pathways are important but insufficient by themselves to produce the complete vestibulo-ocular reflex. Additional neurons, some studied by the authors, are located in nearby parts of the brainstem (in the divisions called the midbrain, pons and medulla; Fig. 1) and in certain other structures. Some neurons located in the medial RF (the core of the brainstem) beneath the IIIrd, IVth, VIth and VIIIth cranial nerve nuclei are active only a few milliseconds preceding fast eye movements. Damage to this part of the RF will paralyze horizontal eye movements. Our electrophysiological experiments were done to characterize the types and interconnections of such neurons.

These experiments were conducted with living cats and measured the electrical responses of neurons and their interconnections, which are called synapses. (Anatomical techniques usually do not determine interconnections.) The neuronal action potential is an electrical pulse of about +100 mV amplitude and 0.5 msec duration which is actively propagated from the cell body down the axon to the terminal(s) without attenuation at a speed of 0.2 to 120 m/sec, depending

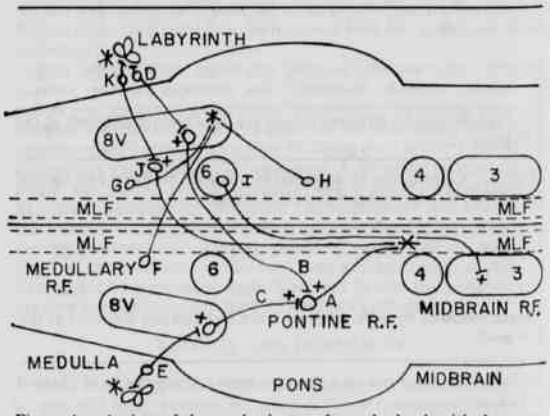

Figure 1. A view of the cat brainstem from the back with the cerebellum removed. The spinal cord is to the left. The motorneurons to the eye muscles originate in cranial nuclei III, IV and VI. The VIIIth nerve connects the labyrinth to the vestibular nuclei (8V). Abbreviations and the neuronal types A-K are described in the text. Asterisks indicate locations of stimulating electrodes.

on the size and type of axon. The longest axons exceed 1m, although the ones studied in these experiments are only approximately 1 cm long. The nervous system transmits information over axons as a series of action potentials.

MATERIALS AND METHODS

The action potential was detected as a weak −0.05 to −2 mV pulse by an extracellularly-located microelectrode placed within 0.1 mm of the cell body. (Because axons produce miniscule extracellular pulses, they are normally undetectable.) An electrical shock to the axon initiated an action potential, which traveled antidromically (backwards) to the cell body, where it was detected by the recording microelectrode. An antidromic pulse always occurred with the same time delay following the shock, because axons conduct at a fixed velocity; the antidromic pulse always occurred at and above the threshold shock strength (the all-or-none rule). The antidromic neurons which were detected followed four shocks at 300 to 1600 shocks/sec (synapses will not usually operate this rapidly). These antidromicity tests proved that the detected cell body projected its axon near the stimulating electrode.

Synapses between neurons were detected by electrically stimulating the presynaptic neurons to produce action potentials in them. These action potentials traveled foward (orthodromically) to the axon terminals, which then released a neurotransmitter chemical into the synaptic cleft. The chemical diffused across the cleft, bound with receptor molecules in the membrance of the postsynaptic neuron, and opened ionic channels. The subsequent flow of ions excited (or, for some synapses, inhibited) an action potential, which was detected by the micropipette (recording electrode). Because of fluctuations in the amount of transmitter released, a post-synaptic action potential sometimes did not occur or occurred at various latencies (e.g., between 0.5 and 3 msec); a synaptically-excited pulse thus easily could be distinguished from the constant-latency antidromic pulse.

Cats were used because they are inexpensive but still make relatively human-like eye movements. In some experiments the cat was anesthetized with pentobarbital. Because this anesthetic depresses synaptic activity, in other experiments an unanesthetized, decerebrated cat was used (short-acting ether anesthesia was used before decerebration). Although this unconscious cat did not make eye movements, neurons could be excited either antidromically or orthodromically to determine connections. The animal's life functions were maintained for the 12-24 hr experiments. After removal of part of the top of the skull and the cerebellum, the brainstem was exposed (the view was similar to that of Fig. 1) so that the electrodes could be inserted visually with micromanipulators. Stimulating electrodes were thin wires, insulated except for the tips. Electrode and neuronal locations were verified after experiments through histological procedures. The referenced papers give further details of methods.

Action potentials were recorded by a glass micropipette with a 10 μm tip diameter and filled with electrically-conductive 4 M NaCl solution. A wire inserted into the micropipette connected it to an amplifier. Signals were displayed upon an oscilloscope and photographed, as shown in our referenced papers. Shocks of 0.1 msec duration and ⩽ 50 μA strength were given to the MLF at 1 mm posterior to the IVth nucleus, where many types of MLF axons pass. The 50 μA shock was strong enough to initiate an antidromic action potential in most MLF axons, but in few surrounding axons. The action potential traveled antidromically to the cell body, where it was detected by the micropipette. In other experiments antidromic action potentials were excited by shocks to the 8V. In various experiments stimulating electrodes also were placed into the labyrinth to excite the VIIIth nerve for testing orthodromic inputs.

RESULTS

Four neuronal categories were studied:

1. **Reticulo-MLF neurons** (type A in Fig. 1) have cell bodies (circle) located in the medial pointine RF and project an axon (line) into the contralateral ascending MLF (Remmel et al., 1978). They also have been observed in anatomical studies (Graybiel, 1977; Cohen, 1974), which indicate that the axons terminate in the midbrain. They might function to coordinate horizontal and vertical eye movements. Most reticulo-MLF neurons receive excitatory (+) synaptic inputs from vestibulo-reticular neurons from both sides (types B and C), which in turn receive excitatory synaptic inputs from VIIIth-nerve fibers (types D and E; Remmel et al., 1979b). Thus a functional VIIIth nerve-vestibular nucleus (synapse), reticular (synapse), MLF pathway appears to exist. Additional interneurons also might contribute. This pathway might transmit head-movement information to the midbrain for controlling eye movements.
2. **Reticulo-vestibular neurons** were observed by shocking the 8V to antidromically excite RF cells (Remmel et al., 1977). They come in (at least) three kinds which are crossed (type F) or uncrossed (type G) from the medulla or uncrossed from the pons (type H). Anatomists (Hoddevik et al., 1974) also have observed them. These neurons might transmit eye- or body-movement signals from the RF to the 8V, where such signals have been detected.
3. **Abducens interneurons** (type I) with cell bodies amidst VIth-nucleus (abducens) motorneurons project their axons up the opposite MLF to terminate upon medial-rectus motorneurons in the IIIrd nucleus (Remmel et al., 1978). These neurons, first clearly demonstrated anatomically (Graybiel and Hartwieg, 1974), carry signals similar to those of lateral-rectus motorneurons and excite medial-rectus motorneurons for the opposite eye (Baker and Berthoz, 1977) to move the two eyes horizontally.
4. **Reticular neurons receiving excitatory monosynaptic input from the VIIIth nerve** and projecting an axon up the opposite MLF (type J) were detected for about 1 mm beneath the traditional anatomical boundary of the vestibular nuclei. Some of them receive monosynaptic excitatory input from VIIIth-nerve neurons (type K). Because these "RF" cells appeared very similar to the 8V cells immediately above them, the vestibular nuclei seem to be effectively larger than previously thought.

DISCUSSION

These studies demonstrated several new types of brainstem neurons and synaptic interconnections. It is impossible here to discuss the many other important neurons and interconnections described by others during the last decade (see Baker and Berthoz, 1977; Brodal, 1974; Cohen, 1974). Neuron by neuron and synapse by synapse, the amazing brain is being understood. Experiments are in preparation to record the behavior of the above neurons during eye movements in alert cats. Although almost all types of neuronal behaviors which the bioengineer might expect to find already have been observed in alert monkeys and cats (Baker and Berthoz, 1977; Cohen, 1974), unfortunately these behaviorally-defined neurons cannot usually be matched with the anatomically-defined types. The puzzle's pieces cannot yet be assembled, but the major outlines of the picture of the oculomotor system will become apparent during the next decades.

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TIME AND LIFE: APPLICATIONS OF MODERN CHRONOBIOLOGY

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ABSTRACT

Chronobiology is that branch of science which objectively quantifies and explores mechanisms of biological time structure. It is an integrating discipline that impacts on all forms of life.

When physiological functions are plotted along a time scale, they appear as regularly repetitive wave forms with means, amplitudes, phasing and periods. In nature these rhythms are found to have many frequencies, from a fraction of a second (ultradian) to a year or more (infradian or circannual); and those with periods of about one day (circadian) have been explored extensively.

Examples of several circadian rhythms are given for experimental animals and man. Evidence is presented to show that it is particularly important to consider biological rhythmicity when interpreting experimental results or attempting to extrapolate from one species to another. An organism is indeed a different biochemical and morphological entity at different times, and it may be expected to react differently to a stimulus at different circadian phases. By taking advantage of natural rhythms in the susceptability to drugs, it is possible to optimize chemotherapy and radiotherapy for cancer and other diseases.

THE RHYTHMIC NATURE OF LIFE

Chronobiology is that branch of science that explores mechanisms of biological time structure (Halberg and Katinas, 1973). Although it is considered a comparatively young science, the writers of ancient times, including the poets, were fascinated with rhythmic phenomena, particularly as they pertained to plants (Scheving, 1976); and many of the important early scientific investigations of rhythmic behavior were performed by botanists. In 1963 E. Bunning summarized the work that had been accomplished, including his own important contributions, and Cumming and Wagner (1968) did a more recent review on plants.

During the past 30 years a great number of publications on rhythms in lower animals and humans have appeared. Rhythms with many frequencies at all levels of biological organization have been demonstrated. Because of the regularity of these rhythms, some refer to them as biological or physiological clocks. Oscillation has been firmly established as a fundamental property of life (Scheving, 1976). Ehert, (1979) considers chronobiology the newest of the four integrating disciplines of biology, ranking in importance with genetics (developmental biology and evolution are the other two).

At the same time that chronobiology was developing at an almost exponential rate, the concept of "homeostasis" continued to be taught in biology classes. Homeostasis, introduced in 1878 by Claude Bernard and championed by Walter Cannon, claims that an organism has capabilities of self-regulation which maintain body fluids and hormones in a rather narrow range by negative feedback, preventing sensitive cells from damage that might be caused by strong variations, including those in the environment. This "steady-state" concept, as taught up to the present time, has governed the thinking of generations of biologists, despite the fact that 40 years ago it already was known that neither body fluids, hormones, organs nor cells exhibit a constant composition.

The range of frequencies that has been found in living systems extends from less than a second to a year or more. It is noteworthy that many correspond to frequencies found in the physical environment such as the approximate 24 hr light-dark cycle brought about by the rotation of the earth on its axis. The rhythms themselves, however, are endogenous, innate and coded in the genome. They will freerun in the absence of a synchronizing force (Scheving, 1976). There is strong evidence that many rhythms are adaptive and serve to adjust organisms in advance to the periodic changes in the environment (Scheving, 1976).

This paper will concentrate on circadian rhythms which have frequencies that correspond to the 24-hr day (circa, about; dies, day). The adjective "diurnal" is sometimes used synonymously with circadian, but it is more appropriate to use this term to describe animals that are active during the day as opposed to nocturnal animals that are active by night. Circadian rhythms are ubiquitous in eukaryotic unicellular and multicellular organisms. Recent data on growth rate of bacteria suggested that circadian as well as rhythms with higher frequencies (ultradian) also may characterize the prokaryotic cell (Sturtevant, 1973); it should be kept in mind, however, that controversy presently exists as to whether the prokaryotic organism is characterized by circadian variation.

Most fluctuations in physiological and biochemical variables are not apparent in the same sense that the pulse, respiratory cycle or menstrual rhythm are; they become overt only when properly measured at frequent intervals along a 24 hr time-scale. Because of their somewhat "invisible" nature, there has been a tendency on the part of some investigators to slight or ignore them in experimental design. In spite of all that is known, they simply have not been accorded the attention they deserve. This undoubtedly is due in large part to the fact that the science is young (Scheving, 1974).

Illustrative Examples: The rhythm in serum steroids was one of the first to be documented and has been studied extensively (Pincus, 1943). This rhythm, illustrated in Fig. 1 for both rat and man, will be used to describe some of the basic properties of rhythms and especially the terminology commonly employed.

In diurnally active man, the adrenal cortex secretes increased amounts of cortisol before awakening, and peak titers are reached shortly after arising. In the nocturnally active rat, the peak of serum cortisterone (predominate steroid of the rodent) occurs shortly before the period of activity begins (Scheving, et al., 1974). The four-fold or greater change in the level of the steroid seen along the 24 hr time-scale (amplitude) clearly shows that these variations are not minor fluctuations around the 24 hr mean, and they cannot be ignored in experimental design (Scheving, 1974). It should be realized that fluctuations with higher than circadian frequencies (ultradian; Weitzman and Hellman, 1974) and lower frequencies (infradian or circannual; Haus and Halbert, 1970) also characterize the rhythm in serum steroid as well as in many other variables. Notice in Fig. 1 that the rhythm in steroids of the nocturnally active rodent is 180° out of phase with the one for diurnally active man. It should be stressed that such a dramatic difference is not always the case, because some of

the other rhythms are not so far out of phase between the two species. Figure 2 illustrates just such a situation where the rhythmic variations in serum prolactin of the rodent and man certainly are not 180° out of phase (Scheving and Dunn, 1974). These observations are important, because they demonstrate that one must be careful when extrapolating from data obtained on the rodent to man. Figure 3 demonstrates the rhythmic variation in the mitotic index of human skin; the maximum cell division in skin takes place at night. Figure 4 depicts the rhythm in DNA synthesis in the bone marrow of the rodent (Scheving and Pauly, 1973). A similar rhythm has been described for the mitotic index in human bone marrow (Killman et al., 1962) (Fig. 5). The rhythmic variations in DNA synthesis or the mitotic index in bone marrow or gut become important considerations when attempting to manage the treatment of a cancer such as leukemia by chronotherapy or radiotherapy.

Figure 6 shows that the histological pattern of glycogen activity in the liver of the rat is dependent on the temporal organization of the organism. In short, even morphology reflects circadian biochemical or physiological changes; however few morphologists consider structural changes with reference to time when interpreting their results (Scheving et al., 1974). Illustrated in Fig. 7 is the reproducibility of rhythms over a 72 hr span in a group of young men. Variables

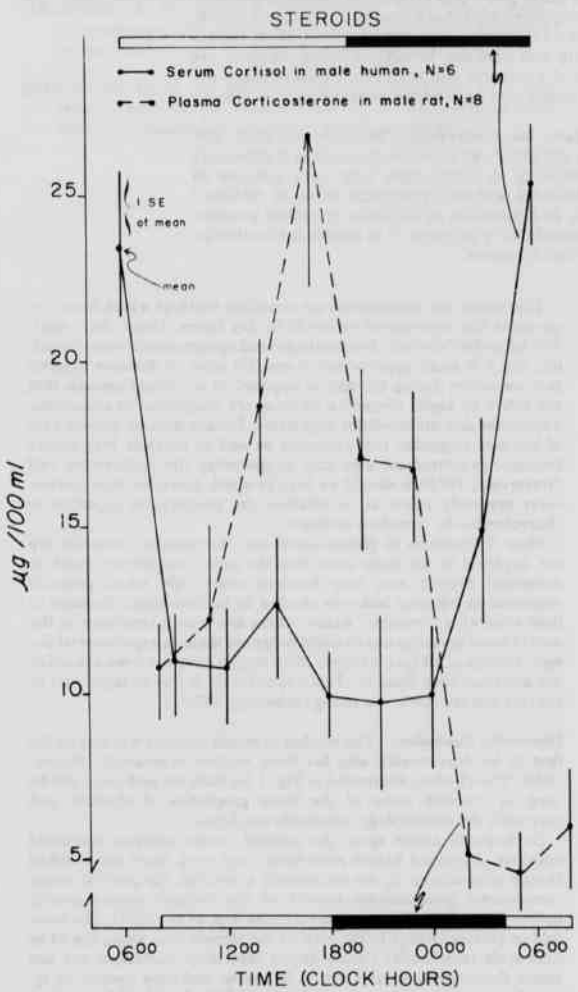

Figure 1. Prominent circadian fluctuation of the predominant serum steroids of rat and man. The rats were standardized to a light-dark cycle (14 hours of light alternating with 10 hours of darkness) and fed *ad libitum* for two weeks prior to the study. For man, the meal times were 0700, 1245 and 1645 hours; rest or sleep time was 2100-0600. The subjects were awakened, however, for sampling at 2400 and 0300. (Scheving, Mayersbach and Pauly, 1974)

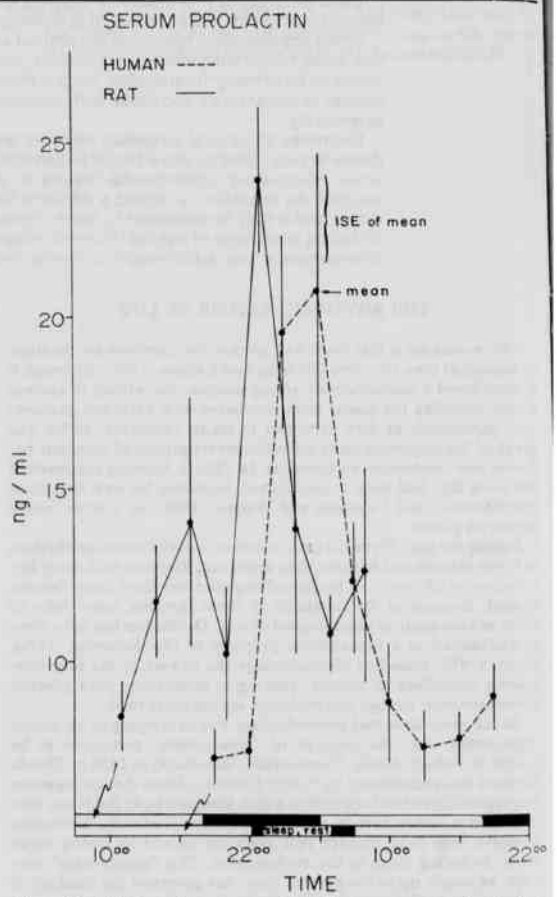

Figure 2. The two chronograms depict the serum prolactin rhythm for man and the rat. Note that the rhythms in the two species are not 180° out of phase as was the case for the serum steroid rhythms illustrated in Fig. 1. Such data caution against extrapolating from data obtained from the nocturnally active rodent to the diurnally active man without knowledge of the rhythmic variation of the variables under consideration. For man, meal times were 0700, 1330 and 1630 hours; rest or sleep time was 2215 to 0700. The subjects were awakened, however, for sampling at 0100 and 0400. N = 13. Rats were fed *ad libitum* and were standardized to 14 hours of light alternating with 10 hours of darkness. N = 8/time point. (Scheving and Dunn, 1974)

measured ranged from oral temperature to the ability to perform mental and physical tasks (Kanabrocki et al., 1973; Scheving et al., 1977) Note that the crest of the rhythm in performance corresponds to the time of poorest performance. Mood and vigor ratings, depicted as chronograms, were determined on a scale of 1-7 by the subjects themselves. It has been shown repeatedly that with minimal training, individuals can accurately monitor their own circadian rhythms for many diverse behavioral and physiological variables, including blood pressure. Halberg has advanced the concept of self-measurement or autorhythmometry (Halberg et al., 1972; Halberg, 1973). Such a concept has already been applied satisfactorily in the monitoring of health and disease (for example, in hypertension). Autorhythmometry promises to have even greater application, especially if it is taught early in life, preferably no later than high school (Halberg et al., 1972).

Figure 8 shows the same data as Fig. 7, but they are depicted after having first been analyzed by an inferential statistical method commonly referred to as the "cosinor". The cosinor technique is one of several objective methods by which time-series data can be analyzed. Essentially the data were fitted to a 24 hr cosine curve by the method of least squares, and the rhythmic parameters were determined; this is readily done by a computer. The rhythmic parameters include "mesor" (overall 24 hr mean if the data are equidistant), amplitude, and acrophase (Halberg et al., 1972). The computer-determined acrophase (point estimate, illustrated by a dot) represents the time when the crest occurs in relation to the rest-activity cycle. The confidence limits also are shown (horizontal bars). Again, it is important to point out that the acrophase for performance corresponds with the poorest performance. The percentage range of change, shown in

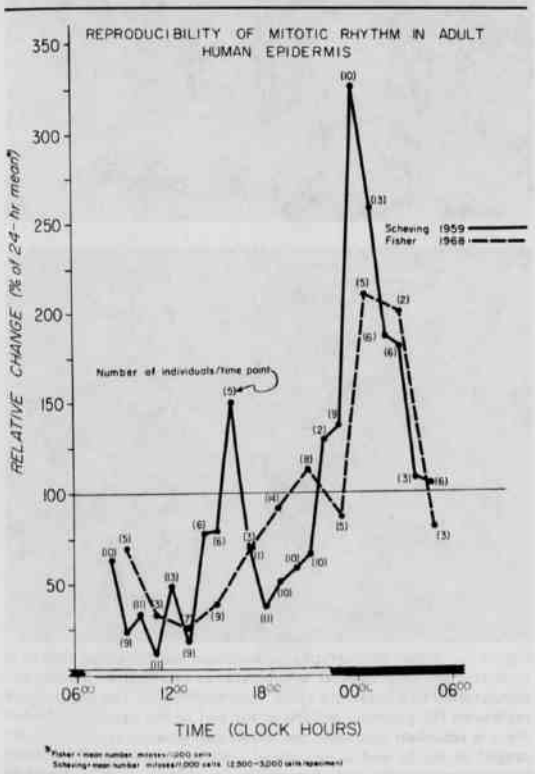

Figure 3. The rhythm in the mitotic index in the adult human epidermis. A majority of the cells divided at a predictable phase of the circadian system. Remarkable reproducibility has been demonstrated in studies done many miles (London and Chicago) and many years apart. (Scheving, Mayersbach and Pauly, 1974)

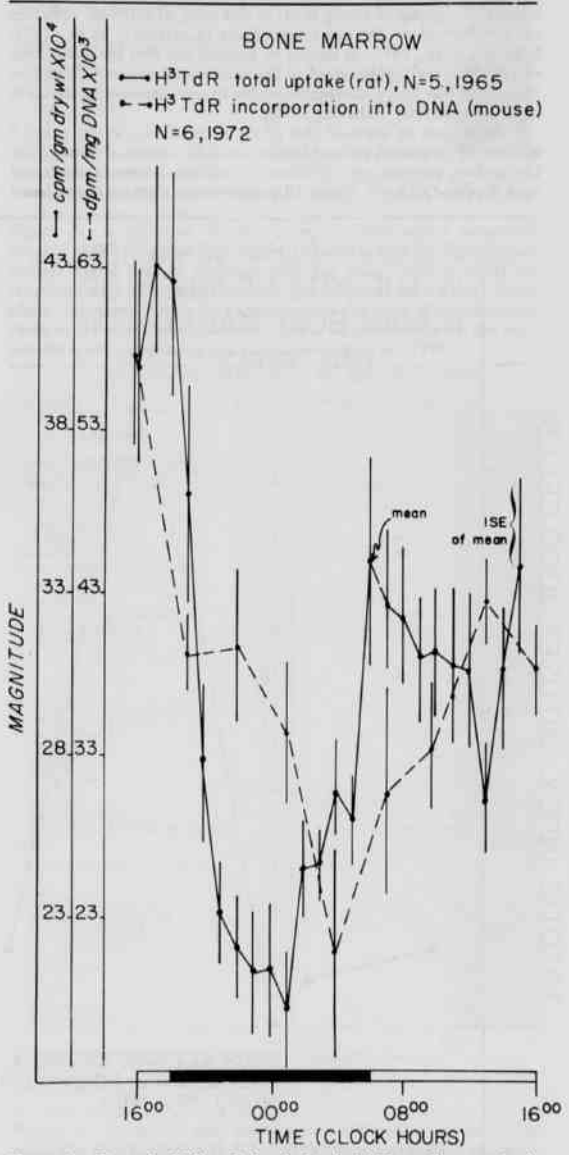

Figure 4. Reproducibility of the rhythm in ^{3}H-thymidine uptake in the bone marrow of rodents. The isotope rhythms were determined by injecting subgroups of animals with ^{3}H-thymidine during a single 24-hour period at the intervals shown on the chronograms. The animals were sacrificed one hour after injection, and the tissues were collected and analyzed by scintillation-counting techniques. (Scheving, 1976)

column 2, is the average difference between the lowest and highest values over the three-day period; temperature, however, is an exception, because the actual change is shown in degrees rather than percentage. Figure 9 is another acrophase map compiled from more extensive data obtained from a different study, two years earlier, on a comparable group of young men. In this case, 41 different variables were measured on the same individuals (Kanabrocki et al., 1973; Scheving et al., 1977). It should be pointed out that the individuals essentially were synchronized to the same social routines. It can be concluded that every variable amenable to measurement oscillates in a rhythmic manner (Scheving, 1976).

It should not be assumed that all variations shown in Fig. 8 and 9 are merely responses to food intake, because certain of these (catecholamines, steroids, etc.) continue to oscillate in lower animals and man deprived of food. Figure 10 compares the rhythms of the heart rate and norepinephrine in subjects fed regular, three-meals-per-day diet, with those rhythms in subjects that fasted for 12 hrs prior to and throughout the sampling. Of course some variables, such as glucose, are strongly influenced by diet (Scheving and Pauly, 1977). Under certain circumstances food-intake can override the strong synchronizing force of the light-dark cycle in animals (Pauly et al., 1977). This can be done by restricting food intake to precise periods for the day, for example to 4-hr spans for rodents or to one meal per day for human beings. Several rhythmic variables can be synchronized in this way, but others show evidence of being synchronized to both the restricted feeding schedules and the light-dark cycle, the net result being a rhythmic waveform demonstrating an interaction between the two potential synchronizing forces (Philippens et al., 1977). Interestingly, other variables remain strongly synchronized to the light-dark cycle in spite of food manipulation (Scheving et al., 1974b).

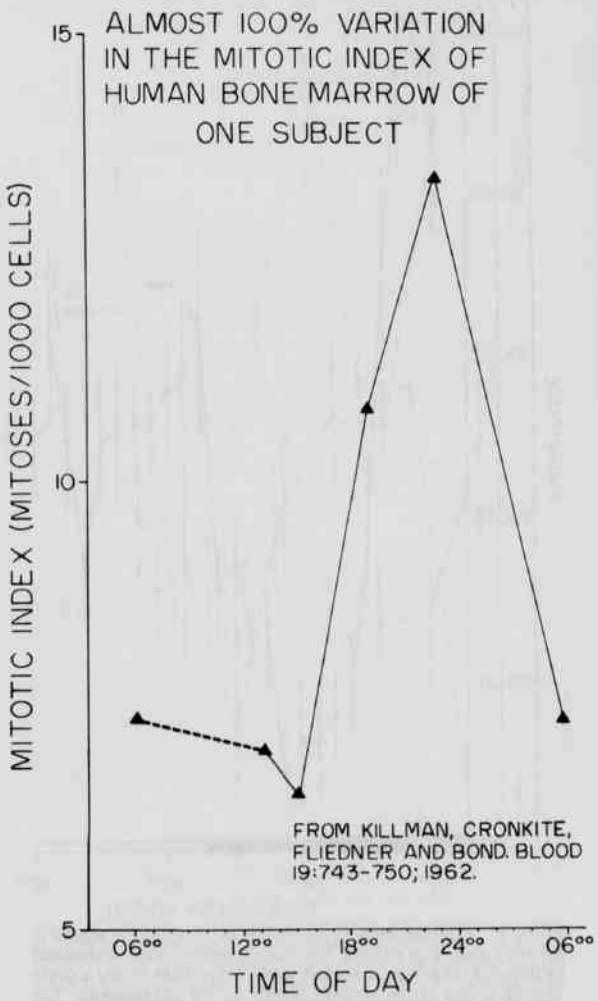

Figure 5. Circadian variation in the mitotic index of bone-marrow cells in a single subject.

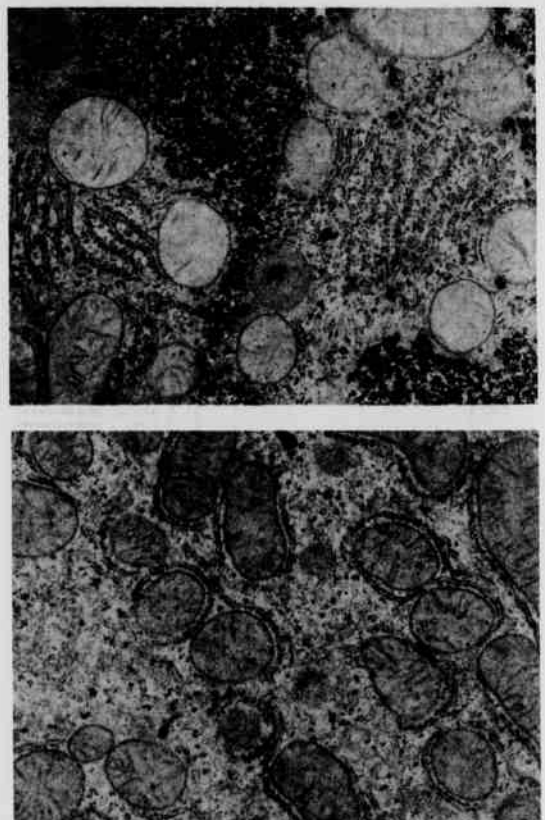

Figure 6. These photographs demonstrate the circadian change in ultrastructure of periportal hepatocytes in rats (fed *ad libitum* and standardized to a light-dark cycle, light 0600-1800). The upper figure represents the glycogen pattern at the end of the dark period when there is abundant glycogen; the rough endoplasmic reticulum is arranged in stacks and is associated with mitochondria. The lower figure represents the end of the light phase when there is almost no glycogen present; the rough endoplasmic reticulum is more evenly dispersed in the cytoplasm surrounding individual mitochondria. Smooth reticulum and free ribosome are clearly visible. x20,000. (Courtesy of H. v. Mayersbach, Hannover, German.)

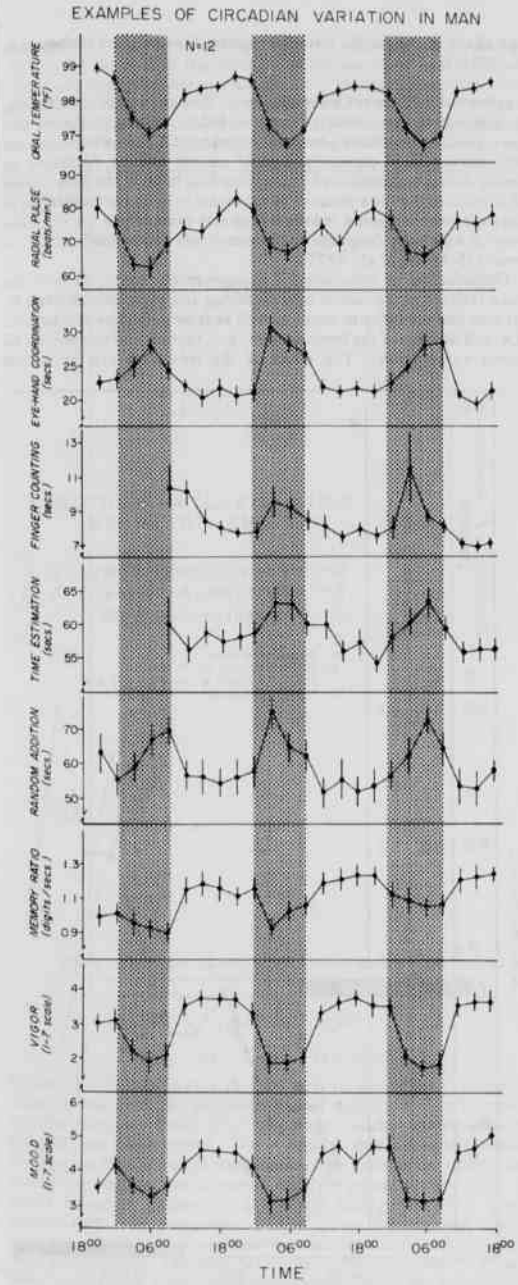

Figure 7. Rhythmic variation in diverse variables in a group of 12 presumably healthy young men over a 72-hour period (sampled at 3-hour intervals). Note that the time of poorest performance represents the crest of the rhythm. Meal times: 0615, 1215 and 1630 hr; rest or sleep time; 2100-0600, however subjects were awakened for sampling at 2400 and 0300 hours. (Scheving, 1977)

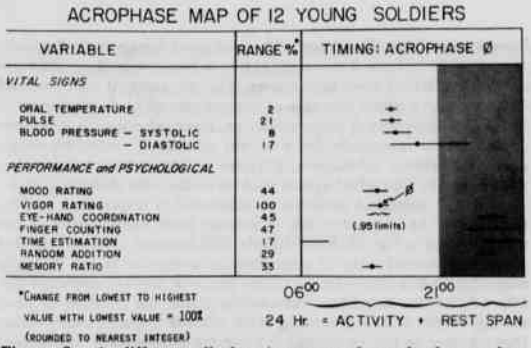

Figure 8. A different display (computer-determined acrophase map) of all the data shown in Figure 7 as well as data on diastolic and systolic blood presure obtained over the same 72-hour span. All measurements were performed on the subjects themselves. Acrophase (represented by a dot) approximates the peak of the circadian cycle in the variables measured, shown with reference to the rest-activity schedule of the subjects. (Kanabrocki et al., 1973)

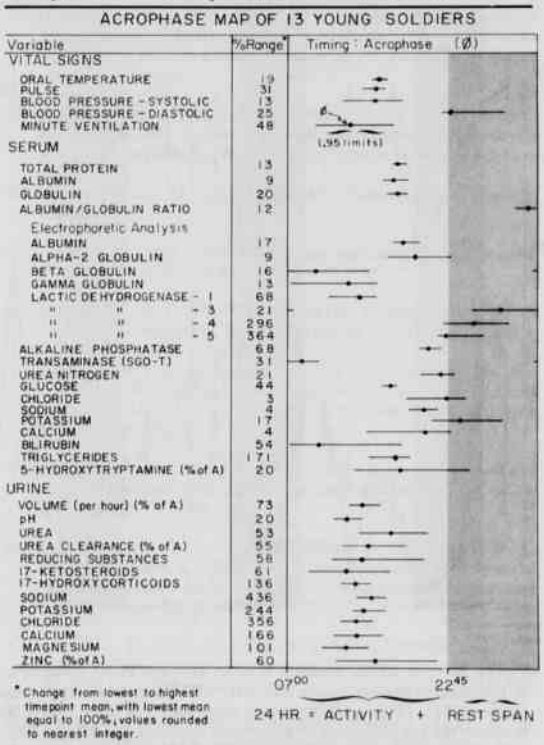

Figure 9. Acrophase map showing data obtained from studies on man. The map illustrates 41 different rhythmic variables in vital signs and in constituents of serum and of urine. Meal times were 0830, 1430 and 1630; rest or sleep time was 2245-0700. The dot represents the time when the crest of the rhythm occurs in relation to the rest-activity cycle. The horizontal bars represent the confidence interval. The center column gives the average 24-hour range of change for the group, that is, the percent difference between the highest recorded means. (Kanabrocki et al., 1973)

Drug Susceptibility Rhythms: The biological system is rhythmically changing; it follows that an organism is biochemically a different entity at different circadian phases. Consequently, it may respond differently to a given stimulus at various circadian stages (times of day). This differential response to an identical stimulus has been demonstrated repeatedly for a variety of stimuli, including drugs, poisons, chemical substances, physical agents such as noise and x-radiation, and biological agents such as endotoxins (Scheving et al., 1974a). The circadian variation as measured in response to various stimuli may be dramatic; this is evident from examination of the chronograms in Fig. 11. For example, the duration of sleep resulting from an identical dose of pentobarbital sodium averages 104 min when the dose is administered to one phase of the rat's circadian system; when it is administered at another phase, the duration of sleep averages only 43 min (Scheving et al., 1968a). Figure 11 also shows that whether or not an animal will survive a potentially lethal fixed dose of amphetamine may depend on the circadian phase at which it is administered. When the dose was given at one phase, 76.6% of the animals survived; whereas at another phase, only 6.6% survived (Scheving et al., 1968b). The third example demonstrates that a carcinostatic drug, cytosine arabinoside (ara-C), is far more toxic at one phase of the mouse circadian system than another (Scheving et al., 1974b).

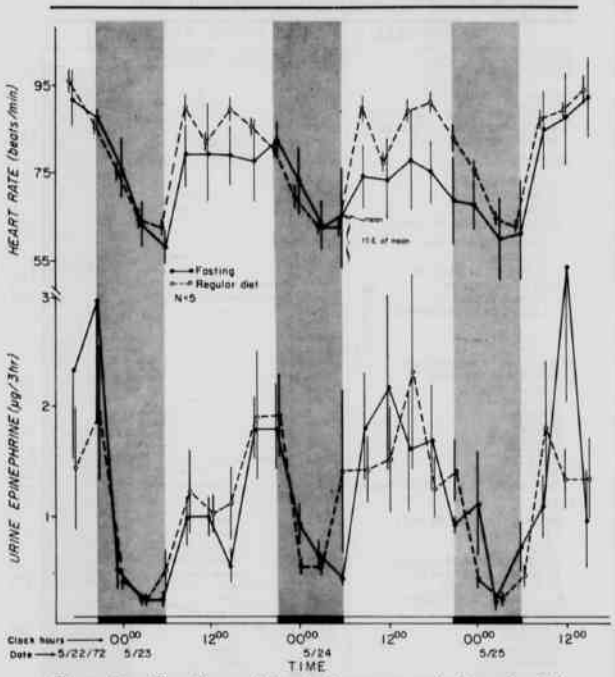

Figure 10. Circadian variation in heart rate and urine epinephrine in presumably healthy young men over a 72-hour span. Meals were eaten at 0615, 1215 and 0630; rest or sleep time was from 2100-0600, however the subjects were awakened for sampling at 2400 and 0300. Note that the group designated as fasting had been subjected to the regular three meal/day schedule through the evening meal of 23 May; after this meal, they did not eat until after the 0600 sampling on 25 May. The only effect noted from fasting was a reduction in the amplitude of the heart-beat rhythm. A third group of subjects all ate a fixed amount of food every three hours over the same period that the one group fasted; and for this group this feeding schedule had no dramatic effect on either variable. The data of the third group are not shown simply to avoid an overly cluttered graph.

Application to Cancer Chemotherapy: Recognition of the variation in response to carcinostatic drugs has led to a series of studies that have produced a critical mass of experimental data which suggests that conventional chronotherapy of cancer can be optimized by timing the administration of drugs according to body rhythms. Figure 12 illustrates one of a number of examples of such optiminization in the experimental mouse, where it is clearly evident that the circadian stage at which the drugs are administered can dramatically affect the results (Scheving et al., 1977).

Optimization of treatment of experimental cancer, in fact, has been realized in the rodent by quantifying and exploiting rhythms in: (1) host susceptibility to drugs as well as their underline mechanisms (i.e. cell division of the bone marrow, gut, thymus and spleen) and (2) tumor susceptibility. The effect of the treatment can be gauged

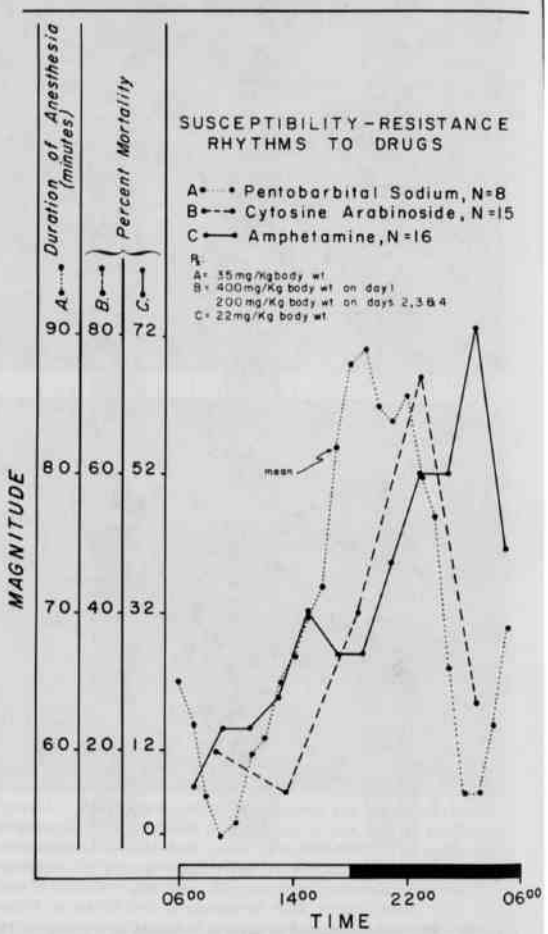

Figure 11. Circadian variation in susceptibility of rodents to pentobarbital sodium, cytosine arabinoside and amphetamine. (For details of each see Scheving et al., 1968a, 1968b, and Scheving et al., 1974b, respectively.)

directly by tumor size, mitotic activity or DNA formation, and indirectly by rhythms in temperature of the tumor or excretory products such as polyamines, certain amino acids and light-chains in the case of immunocytoma in LOU rats (Halbert et al., 1977).

It is concluded that consideration of time structure of organisms as revealed by their rhythms, may lead to the elucidation of many unexplained biological mechanisms. First, however, the "dogma" of a "constancy of the internal environment" either has to be abandoned or modified. Biologists must think in terms of all life being a composite of highly organized rhythmic events. When this is widely recognized, there will follow a new era of progress in biology and medicine.

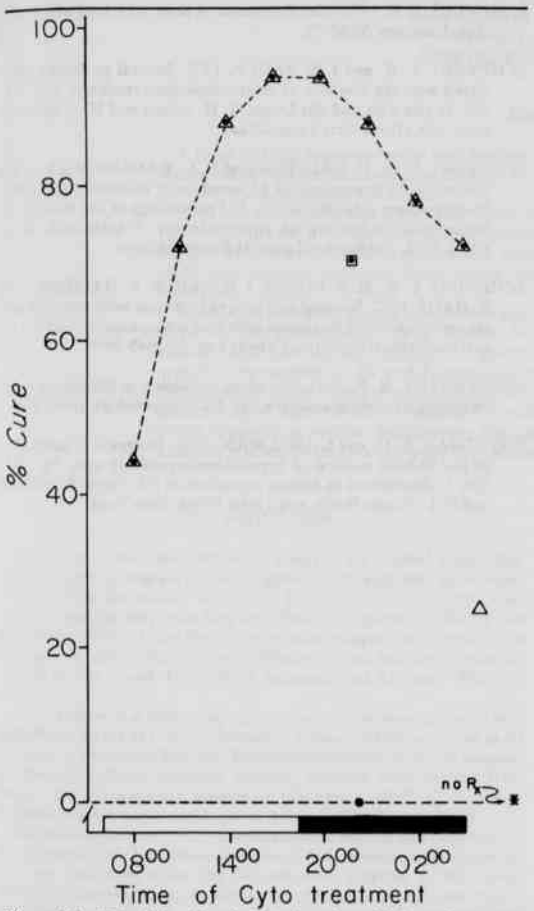

Figure 12. The △ implies that the best sinusoidal ara-C treatment schedule was used (the chronobiological approach). The □ implies that the reference schedule of treatment (non-chronobiological approach) was administered. The • implies that cyclophosphamide (cyto) was administered in combination with ara-C once/course (four courses) to each mouse; however, different groups received it at different circadian phases ◬. Horizontal scale, time when cyclophosphamide was administered. The group that did not receive cyclophosphamide is shown just the right of the time scale. N for each group was 20. The important point is that cure rate (% of mice alive 75 days after tumor inoculation) ranged along the 24-hour time scale from 44% to 94% and **none** of the animals receiving the chronobiological approach died of acute drug toxicity whereas **30%** of the animals receiving the non-chronobiological treatment died from acute drug toxicity. Only 25% of the animals receiving ara-C alone were cured, △, and none were cured that had received cyto alone, •. For details of this study, see Scheving et al. (1977).

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THE SYSTEMATIC STATUS OF THE FISHES OF GENUS *CAMPOSTOMA* (CYPRINIDAE) INHABITING THE MAJOR DRAINAGES OF NORTHERN ARKANSAS

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ABSTRACT

A total of 6980 morphometric and meristic data points were analyzed from specimens previously identified as *Campostoma anomalum pullum* and *Compostoma oligolepis* from all areas of their Ozark ranges in Arkansas.

Data were analyzed using the Statistical Analysis System (SAS) and IBM 370 Computer System (HASP II). An attempt was made to establish separation points through multivariate analysis (MANOVA) by taxon and watershed. Additional analyses included factor analysis and discriminant function analysis. Scale count frequencies were analyzed using computer program MINITAB.

MANOVA revealed a lack of consistent separation points, and Ozark populations were shown to be distinct and highly variable from one watershed to another. Factor analysis revealed high correlation among morphometric characters (r>.8), high correlation among meristic characters (r>.8), and biologically insignificant correlation between the two sets of data. Discriminant function analysis classified 77.57% of all Ozark specimens as *C. a. pullum*, regardless of scale count. Frequency distribution analysis of scale counts for Ozark specimens revealed a normal distribution indicative of a single-species sample. Validity of subspecific status for taxon *oligolepis* in Arkansas Ozark populations is implied.

INTRODUCTION

Controversy over the systematic status of the central stoneroller, *Campostoma anomalum pullum* (Agassiz), and largescale stoneroller, *Campostoma anomalum oligolepis*, Hubbs and Greene, has continued since the latter was first described as *oligolepis* by Hubbs and Greene in 1935. At that time, the taxon *oligolepis* was thought to be endemic to the driftless area of Wisconsin but has since been reported in the Ozark Uplands of Arkansas and Missouri (Pflieger, 1975).

C. a. pullum is a wide-ranging form, occurring west of the Mississippi River as far as eastern Nebraska, Kansas, Oklahoma, and as far south as northcentral Mexico. This subspecies also occurs in extreme northwestern Ohio, northern Indiana, extreme southwestern Kentucky, and southwestern Mississippi (Trautman, 1957). *C. a. pullum* is found in most major drainages in Arkansas (Buchanan, 1973).

Hubbs and Greene (1935) considered taxa *pullum* and *oligolepis* to be subspecies of *C. anomalum* although little evidence of intergradation was indicated where the two occurred together in Wisconsin. Their decision was based on the intermediacy of certain characters of the Ohio stoneroller, *C. a. anomalum*, between taxa *oligolepis* and *pullum* (Pflieger, 1971), particularly scutellation.

Pflieger (1971), in examining Missouri forms of *C. a. pullum* and *C. oligolepis*, pointed out that scale counts from northern and southeastern Ozarks (the Osage, Meramac, and Gasconade rivers, and headwater diversion systems) are similar to those of Wisconsin populations reported by Hubbs and Greene (1935), but are consistently lower than those of the southern Ozarks (the White, Black, and St. Francis rivers). He further noted that variation was not clinal. Scale counts for headwater diversion systems were as low as those from the northern Ozarks, despite the proximity of populations with higher counts. Taxon *pullum* was further found to occupy several of these small Ozark headwater streams to the complete exclusion of *oligolepis*, although no locations were found where the reverse was true.

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Commonly used key characters (counts of lateral line scales, circumferential scales, lateral line-circumferential sum, and predorsal scales) which have proven effective in separating the two in northern portions of the range of *oligolepis* (Burr, 1974; Burr and Smith, 1976; Smith, 1978) are inconclusive in Arkansas due to overlapping counts.

The purpose of this study, therefore, was to examine the sources and degree of morphometric and meristic variation existing between populations of the genus *Campostoma* inhabiting the waters of northern Arkansas, in an effort to gain a better understanding of the systematic position warranted by them.

METHODS AND MATERIALS

Specimens employed in this study were either collected or obtained from catalogued collections in the Arkansas State University Museum (ASUMZ), and uncatalogued specimens at the University of Arkansas, Fayetteville. Catalogued collections (ASUMZ) containing specimens from the Caddo and Saline rivers of southern Arkansas, and uncatalogued specimens from the Roanoke River, Virginia, were employed for comparison. The latter have been tentatively identified as *C. a. michauxi* (Buth and Burr, 1978).

Collections were made by use of standard minnow seines (0.64cm mesh and 1.82m depth) of 3.04, 4.57, 6.10, and 7.62 meters in length, as well as an engine-powered electroshocker (O/R Engine, Inc., type 214).

Separation for analysis was by use of the key character of Buchanan (1973) based on Pflieger (1971). This was a combined circumferential and lateral line scale count of 75-87 for *oligolepis* and 89-101 for *pullum*.

The character set used was developed from characters used in past morphometric and meristic studies (Sewell, 1979), particularly those used by Ross (1952) in separating eastern forms of *C. anomalum*, and those used by Burr (1974) in separating *Campostoma* specimens of the upper Mississippi River Valley. Specimens employed were 50mm, or more, in standard length to minimize effects of allometric growth.

Meristic characters employed were counted by the direct count method, using an American Optical dissecting microscope (30 and 90), as well as a Casper 4X and 8X hand-held lens. An American Optical 7.5v light source was used for illumination. Meristic variables were circumferential scales, lateral line scales, predorsal scales, scales above the lateral line, anal rays and pectoral rays.

Morphometric characters were measured using Helios dial calipers, to the nearest 0.1mm. Morphometric variables were head length, trunk length, standard length, total length, snout to dorsal fin distance, snout to pectoral fin distance, snout to anal fin distance, snout to lip distance in ventral view, gape width, depth, eye to eye distance, eye diameter, and least depth of caudal peduncle.

Computer analysis was accomplished using the IBM-370 operating system at the University of Arkansas, Fayetteville. Analysis of data was by use of the Statistical Analysis System (SAS), using factor analysis, multivariate analysis of variance (MANOVA), and discriminant function analysis packages (Barr et al., 1976). MANOVA analyzed each variable between data groups and computed simple statistics for each variable in test groups, taxon and watershed. Computed F values and probabilities were analyzed in a determination of significance between group differences for each variable. A $P > F$ value of 0.0009 or less, was used to determine conclusive significance.

Figures, summarizing encountered variation, were computer prepared. Computer system MINITAB was used for simple mathematics and graphs (Ryan et al., 1976).

RESULTS

The first factorial axis (factor 1) accounted for 60.9-67.0% of all variation observed in the data swarm. The second factorial axis (factor 2) accounted for an additional 14.5-21.8% of all variation, for a combined total of from 75.4 to 88.8%. Due to the large degree of total variation accounted for by these two axes, remaining variation was not plotted by MANOVA, and deemed biologically insignificant.

The factor 1 axis represented an interaction of the various morphometric characteristics (values 0.77-1.0), with the pectoral ray variable loosely associated with it (values 0.58-0.89). The factor 2 axis was associated with the various meristic characteristics, with all values falling within the range of 0.61 to 1.0, except the pectoral ray variable (values −0.52 to 0.87).

Analysis of *oligolepis* populations by watershed revealed several significant differences. Head length, snout to dorsal fin distance, snout to pectoral fin distance, snout to anal fin distance, standard length, total length, trunk length, snout to lip distance, circumferential scale count, lateral line scale count, eye to eye distance, eye diameter, and least depth of caudal peduncle were significantly different from one watershed to another. In addition, pectoral ray count, body depth, and gape width variables approached significance in their differences. MANOVA generated test criteria F scores of 5.39 (Hotelling-Lawley Trace), 5.02 (Pillai's Trace), and 5.21 (Wilks' Criterion). A $P > F$ of 0.0001 was observed in all three cases, and the null hypothesis of no overall watershed-related effect, rejected.

Scattergram of factor scores for this test (Fig. 1) reveals that factor 1 mean values for watersheds #2 (Black River) and #3 (White River) are highly similar, indicating a high degree of morphological similarity between these two populations, while watershed #1 (St. Francis River) is significantly displaced. Mean factor values further indicate that watershed #3 and watershed #1 specimens demonstrate the greatest degree of meristic similarity, of the three. Mean values for factor 1 in the St. Francis, Black, and White rivers were −0.7637, 0.2179, and 0.1907, respectively. Mean values for factor 2 within these systems were −0.2398, 0.3566, and −0.2226, respectively.

Analysis of taxon *pullum* populations by watershed yielded significant differences for all variables except gape width, and pectoral ray counts. MANOVA generated test criteria F scores of 10.51 (Hotelling-Lawley Trace), 6.84 (Pillai's Trace), and 8.58 (Wilks' Criterion). The $P > F$ in each case was 0.0001, and the null hypothesis for watershed effect, rejected.

Characteristic vectors provided by MANOVA were used to convert factor scores to adjusted canonical variate scores for the purpose of graphic representation (Fig. 2), due to the high incidence of overlap and confusion encountered. Factor 1 means provided by MANOVA, however, revealed that watershed #1 and watershed #6 (Saline River) were similar morphometrically (μ = −0.8568 and −0.6590, respectively). Similarly, watershed #2 and watershed #5 (Caddo River) grouped together (μ = −0.1258 and −0.0875, respectively), as did watersheds #3 and #4 (Roanoke River) with mean values of 0.5295 and 0.5806, respectively. Meristic values (factor 2) likewise separated three distinct groups. Watersheds #1, #2, and #3 (northern Arkansas drainages) were meristically similar (μ = −0.3988, −0.6312, and −0.2538, respectively). The Caddo River and Roanoke River specimens were similar meristically (μ = −0.6025 and 0.5031, respectively) while the Saline River specimens were significantly displaced from all others with a mean value for factor 2 of 1.3394.

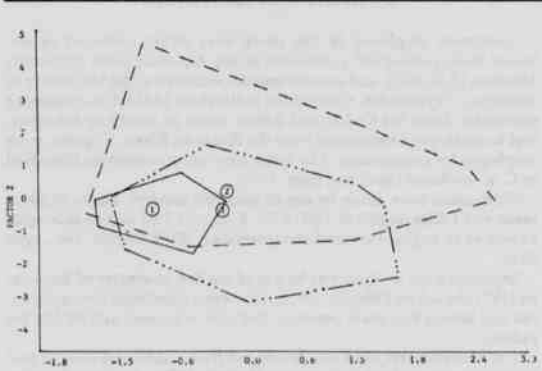

Figure 1. Scattergram of the results of factor analysis of Arkansas *Campostoma oligolepis* specimens by watershed (1 = St. Francis River, solid line; 2 = Black River, dashed line; 3 = White River, dash-dot line). Numerals indicate mean position.

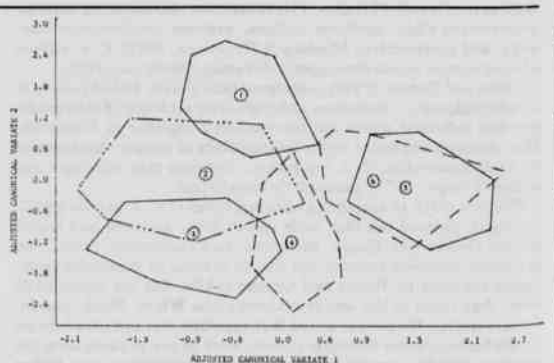

Figure 2. Scattergram of adjusted canonical variates calculated from factor analysis of selected populations of *Campostoma anomalum pullum*, by watershed (1 = St. Francis River, AR; 2 = Black River, AR; 3 = White River, AR; 4 = Roanoke River, VA; 5 = Caddo River, AR; 6 = Saline River, AR, dashed line). Mean values indicated by numeral position.

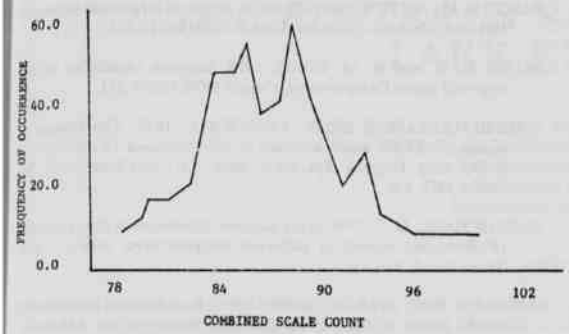

Figure 3. Frequency of occurrence of combined scale counts of lateral line and circumferential scales in genus *Campostoma* specimens from the major drainages of northern Arkansas.

Analyzation by taxon within each watershed produced significant differences only in scale count variables. In the White River, the two taxa were significantly different in circumferential scale count, lateral line scale count, predorsal scale count, and scales above the lateral line. In the Black River, the two populations significantly differed only in the circumferential scale count. In the St. Francis River, significant differences were noted in circumferential scale count and lateral line scale count.

To further analyze the scale counts producing significant differences in northern Arkansas, the frequency of occurrence of each combined count of circumferential and lateral line scales within the combined ranges of the two taxa (78-100) was plotted (Fig. 3). A continuous array of values was produced from a low of 78 to a high of 100. Modal counts for the White, Black, and St. Francis rivers were 89, 86, and 84, respectively. The overall mean count for northern Arkansas specimens was 85.97. The curve produced is typical of the normal distribution of a single population (Book, 1978). In each watershed, three modes of concentration were observed (Sewell, 1979). The smaller extreme modes may represent pure line individuals, while the larger central mode may represent intergrades.

Discriminant function analysis employed reference groups from the upper Black River. All remaining specimens were analyzed as unknowns. Of those specimens originally classified as *oligolepis*, 77.6% were reclassified as *pullum*. Of those specimens originally classified as *pullum*, 23.3% were reclassified as *oligolepis*. These results indicated a mingling of overall characteristics above and below the original separation points, with the majority of all specimens examined revealing a closer relationship with *pullum* calibration group.

The correlation matrix generated with discriminant function procedure revealed all morphometric characters to be highly correlated ($r > .8$) except snout to lip distance ($r = .3$ to $.8$). All morphometric variables were poorly correlated with meristic variables (low negative values). Scales in the lateral line and circumferential scales were highly correlated ($r > .8$). Scales above the lateral line and predorsal scales were less intercorrelated ($r = .04$ to $.8$). Pectoral ray counts revealed no biologically significant correlation with any other variable ($r = -.2$ with other meristics, and .3 with all morphometrics).

DISCUSSION

In the original assignment of specimens into taxa for analysis, the key characters suggested by Buchanan (1973), based on Pflieger (1971), were used. These were a sum of lateral line and circumferential scales of 75 to 87 for taxon *oligolepis*, and 89 to 101 for *pullum*. However, if this separation were valid, discriminant function analysis results should have agreed with our original assignments. Furthermore, no other areas of consistent difference were detected by MANOVA.

Lateral line scale number in the genus *Campostoma* has been shown to be influenced by temperature (Carmichael and Aspinwall, 1977; Carmichael, 1979). Individuals raised at a lower mean temperature (13.9°C) were shown to have significantly more scales in the lateral line than those raised at a higher mean temperature (24.3°C). Studies in the Buffalo River (Cashner and Brown, 1977) seem to substantiate these findings, in that collections in the headwater regions with lower mean temperatures (25-28°C, to 28-31°C, downstream) contained a higher number of specimens identified as *pullum*, often to the complete exclusion of *oligolepis*. Longer developmental periods typically produce higher counts in meristic structures (Hubbs, 1926) and developmental rate has been shown by many researchers to vary directly with temperature (Barlow, 1961).

Other methods have been used in conjunction with scale counts to separate these two taxa. Coloration, tubercle pattern, and general body form of males in breeding condition were employed by Burr (1974), Smith (1978), and Pflieger (1975). In Arkansas, however, the combined lateral line and circumferential scale count used as a key character, regularly places specimens exhibiting both tubercle patterns in the same taxon (Sewell, 1979). Wiley and Collette (1970) believed nuptial tubercle patterns to be related to breeding habits. Burr and Smith (1976) suspected tubercle differences to be related to spawning behavior. Branson (1962) pointed out that extensive tubercle development in Ozark minnows (Cyprinidae) was associated either with very active spawners, or those spawning in rapidly flowing waters. Koehn (1965) found that tubercle patterns in the breeding males of the Red Shiner, *Notropis lutrensis*, were highly variable. In the absence of additional supporting characters, nuptial tubercle patterns are of little value in separating species. The breakdown of this character as a specific indicator in Arkansas *Campostoma* was further illustrated by discriminant function analysis. Coloration differences noted by Burr and Smith (1976) agree with conditions encountered in this study in that older, larger breeding males which lacked a crescent-shaped row of tubercles beside the nostrils, frequently displayed limited black pigmentation of the anal fin.

Cloutman (1976) differentiated the two taxa in the White River on the basis of parasite fauna, particularly the number of *Crassiphiala bulboglossa* Van Haitsma. Numbers of this parasite increase with the length and age of the fish, presumably as a function of exposure time. Of those specimens identified as *oligolpis* by Cloutman, 43% were over one year of age, or age group 1, while only 5% of those specimens identified as *pullum* were age group 1. All others were age group 0. A higher incidence would therefore be expected in the *oligolepis* group due to exposure time, and not necessarily due to host susceptibility.

Buth and Burr (1978) presented electrophoretic evidence in support of specific status for *oligolepis*. However, it should be noted that *oligolepis* specimens from Illinois exhibited "an unusually high degree of genetic variability, high heterozygosity levels, and shared several variate alleles with *C. a. pullum*" specimens from Illinois. *C. oligolepis* specimens from Missouri did not exhibit these genetic similarities with *pullum* specimens from Illinois; however, *pullum* specimens from Missouri were not used for comparison. Furthermore, Illinois and Missouri populations of *oligolepis* exhibited the lowest genetic similarity coefficient ($I = 0.94$) encountered in any intrataxon test group employed. Incorporation of Missouri *pullum* specimens may have revealed the close genetic relationship observed in Illinois specimens.

During this study, no evidence was found that would indicate granting specific status to the taxon *oligolepis* in Arkansas. This conclusion was supported by the following observations: absence of consistent significant morphological differences; absence of meristic differences except those supplied with the original identification of specimens; invalidity of nuptial tubercle patterns as discriminators; presence of intergrades between previously nonintegrating taxonomic entities; and graphic curve of combined lateral line and circumferential scales atypical of separate species.

External characters which have proven effective discriminators in other parts of the range of *oligolepis* were not useful for separation of these two taxa in Arkansas. In the upper Mississippi River Valley, Burr and Smith (1976) reported 99.8% separation using the sum of circumferential and lateral line scales as a specific indicator, and a count of 85 as "break." Ecological differences reported by Burr and Smith (1976) parallel those encountered in this study, but no confident point for separation was found.

Bailey (1956) asserted that *oligolepis* is either a full species or an environmental variant, and favored the latter view. MANOVA results support this view, as indicated. Variation within the genus *Campostoma* in Arkansas appears to be regulated by highly variable environmental conditions, presumably during development, coupled with the fact that members of the genus in Arkansas are highly responsive to local environmental conditions as indicated by interwatershed analysis. This degree of variability was reported by Burr and Smith (1976). The evident presence of intergrades in Arkansas waters further supports the view of *oligolepis* as an environmental variant. Based on our results, the validity of the trinomial *C. a. oligolepis*, originally applied by Hubbs and Greene (1935), is indicated.

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ESTIMATED GROWTH AND STANDING CROP OF LARGEMOUTH BASS *(MICROPTERUS SALMOIDES)* FROM LAKE ELMDALE

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ABSTRACT

Electro-fishing gear was used to make shoreline population estimates of largemouth bass *(Micropterus salmoides)* in Lake Elmdale, Washington County, Arkansas, during September 1979. The population density was estimated to be 1541 bass/Km² with a standing crop of 30.4 kg/ha. The length-weight relationship was calculated as $W = 0.00001504L^{2.97}$, and the total length-scale radius relationship as $L = 41.75 + 1.23S_r$. The average condition coefficient(K) was 1.31. In comparison with four other Arkansas lakes the population density of largemouth bass was highest in Lake Elmdale while the growth rate was lowest.

INTRODUCTION

The largemouth bass is an important game fish in the United States and Arkansas (Bryant and Houser, 1971). In order to better manage populations of largemouth bass in reservoirs and lakes, studies on the growth, population size, and feeding are necessary. Numerous studies on Arkansas largemouth bass populations have been conducted (Aggus and Elliott, 1975; Applegate et al., 1966; Kilambi et al., 1978; Olmstead, 1974) as well as studies on bass populations in other areas of the country (Bennett, 1950; Byrd and Moss, 1957; Hooper, 1975; Ridenhour, 1960; Swingle and Smith, 1942; Von Geldern and Mitchell, 1975).With this wealth of information on bass populations, it is unfortunate that some smaller lakes such as Lake Elmdale have never been studied. This paper represents the first published study of this small reservoir which has some interesting features.

Lake Elmdale, owned by the Arkansas Game and Fish Commission, is located on Bush Creek in Washington County, Arkansas, about four miles west of Springdale. It was impounded in 1953 and contains underground deficiencies. The limestone formations beneath the dam allow leakage, which causes a wide fluctuation in the water level (Kaffka, 1967). This was evident during the study, when after two weeks a return trip to the lake showed that the water level had fallen 15 to 20 cm. The surface area is about 80 ha with a shoreline of 5.8 Km.

METHODS AND MATERIALS

Largemouth bass were collected by a boat-mounted 230 volt AC electroshocker on six nights from 11 to 20 September, 1979. All bass were measured for total length to the nearest millimeter, and scale samples from all fish were removed from the body at the tip of the apposed left pectoral fin. Bass for the length-weight analysis were collected only on the last trip. The bass were weighed to the nearest gram. Scales were pressed in plastic and read by use of an Eberbach scale projector with a magnification of 40x. For the population estimate the bass were caught and released after marking them by clipping the anal fin.

RESULTS

The length-weight relationship was calculated as:

$$W = aL^b$$

where W = total weight in grams, L = total length in millimeters, and a and b are constants. Based on 211 largemouth bass this relationship was described by the equation:

$$W = 0.00001504L^{2.97}$$

The slope of 2.97 was not significantly different from 3.0 ($t_{210} = 1.45$) indicating isometric growth.

The condition coefficient ($K = W/L^3 \times 10^5$), for Lake Elmdale largemouth bass ranged from 0.95 to 1.48 with an average value of 1.31. This value was similar to Crystal Lake largemouth bass (Kilambi et al., 1978) and higher than the bass from Lake Fort Smith, 1.19 (Olmsted, 1974). The coefficient was highest (1.54) for largemouth bass from Beaver reservoir (Bryant and Houser, 1971).

For the total length-scale radius analysis, a total of 96 bass were used. The relationship was estimated by the linear regression equation:

$$L = 41.75 + 1.23S \; (R = 0.95)$$

Lengths attained at earlier ages were calculated using the total length-scale radius relationship (Table 1). Comparison of growth of Lake Elmdale largemouth bass with those of other bodies of water in Arkansas (Table 2) indicated a lower growth rate for the bass in Lake Elmdale.

Growth data were fitted to the von Bertalanffy growth equation (Ricker, 1975):

$$L_t = L_\infty(1-e^{-k\,t-t0})$$

where L_t = length at age t, L_∞ = maximum attainable size, k = rate constant (coefficient of catabolism), and t_0 = age at which the length is zero. The Bertalanffy model describing the growth of the Lake Elmdale largemouth bass was expressed as:

$$L_t = 650(1-e^{-0.08\,t\,+\,2.4})$$

The lengths calculated by the Bertalanffy growth formula and by back calculation from the total length-scale radius relationship when fitted to a linear regression were in agreement ($r = 0.99$) indicating the suitability of this growth model to describe the growth of largemouth bass.

A total of 1,934 bass were marked, and 13.1% were recaptured. The population size was estimated by the Schnabel Method (Ricker, 1975) to be 8,937 with 95% confidence limits of 7,835 and 10,037. Of the total population, 47% of the bass were less than 150 mm.

The biomass of largemouth was estimated to be 30.4 kg/ha with bass less than 250 mm in length being 23.4 kg/ha and bass more than 250 mm in length making up 6.9 kg/ha. The estimated standing crop for Lake Elmdale largemouth bass was much greater than those of Beaver Reservoir or Bull Shoals (Table 4).

Population density expressed as number of largemouth bass per kilometer of shoreline was compared with four lakes in Arkansas (Table 3). The densities are comparable since the population estimates were obtained by the Schnabel Method. Population density was highest in Lake Elmdale and lowest in Lake Fort Smith. In Lake Elmdale and Crystal Lake the population densities were higher than in Beaver Reservoir and Lake Fort Smith. The higher densities in Lake Elmdale and Crystal Lake were likely due to frequent stockings by the Arkansas Game and Fish Commission and better survival of young-of-the-year bass.

A comparison of largemouth bass average annual length increments during the first six years of life (Table 2), and population density in five Arkansas Lakes (Table 3) by linear regression showed a significant decrease at the 0.05 level in growth with increasing density ($R = 0.92$). However, the length increment of 74 mm for Lake Fort Smith with the lowest density was smaller compared to Beaver (79 mm) and Bull Shoals (82 mm) Reservoirs having greater densities of largemouth bass population. Growth increments of 54 and 62 mm for bass from Lake Elmdale and Crystal Lake, respectively, were less than in bass from the other three lakes. The observations indicate that factors other than population density may also influence growth.

DISCUSSION

Lake Elmdale had the highest population density and slowest growth rate for largemouth bass of five Arkansas lakes. Availability of suitable forage fish is an important factor influencing growth. The diet of Lake Fort Smith bass was predominantly bluegill, *Lepomis macrochirus*, with young gizzard shad, *Dorosoma cepedianum*, occurring in early summer diet (Olmsted, 1974). In Beaver and Bull Shoals Reservoirs, gizzard shad and threadfin shad, *D. petenense*, are abundant (Houser and Dunn, 1967; Houser and Netsch, 1971) and were the most common forage fishes in the diet of largemouth bass (Applegate et al., 1966; Applegate and Mullan, 1967; Aggus and Elliott, 1975). Fish, especially bluegill, was the major food item for the Crystal Lake bass less than 170 mm, and above this size crayfish and fish, predominantly bluegill, were most important (Wickizer, 1978). In Crystal Lake, bluegill was the most abundant of all lepomids (Kilambi et al., 1976). Based on the number of fish observed during the period of bass population estimation, bluegill is the dominant lepomid in Lake Elmdale and is presumed to be the primary forage for Lake Elmdale bass.

In Beaver and Bull Shoals Reservoirs and Lake Fort Smith, the population density of largemouth bass was low, with Lake Fort Smith being the lowest. However, the growth of the Lake Fort Smith bass is lower than in Beaver or Bull Shoals Reservoirs. One difference is that the main forage fish for bass in Lake Fort Smith is bluegill which has been shown to be less suitable forage than other fishes for largemouth bass (Dendy, 1946; Bennet, 1950; Lewis and Helms, 1964; Aggus, 1972; Olmsted, 1974). While bluegill is not considered to be suitable forage for bass, largemouth bass feeding on threadfin shad exhibited improved growth (von Geldern and Mitchell, 1975). It appears that even though largemouth bass are more dense in Beaver and Bull Shoals Reservoirs than in Lake Fort Smith, the forage of bluegill is less suitable for the growth of largemouth bass than shad.

In Lake Fort Smith, Crystal Lake, and Lake Elmdale the forage fish is largely bluegill. However, the population density is highest in Lake Elmdale, intermediate in Crystal Lake, and lowest in Lake Fort Smith. The population density is inversely related to the growth rates which is poor in Lake Elmdale, intermediate in Crystal Lake, and good in Lake Fort Smith. The extremely high density of largemouth bass in Lake Elmdale was probably due to fertilization. The Arkansas Game and Fish Commission periodically applies inorganic fertilizer to the lake and further, the run off from the surrounding poultry industry adds organic fertilizer. It has been shown that fertilization of ponds will increase fish production (Swingle, 1949; Swingle and Smith, 1942; Byrd and Moss, 1957). In Lake Elmdale largemouth bass

Table 1. Back-calculated total lengths of Lake Elmdale largemouth bass.

Age group	Number of fish	Total length (mm) at each annulus 1	2	3	4	5	6	7
I	16	138						
II	18	160	210					
III	4	148	180	223				
IV	10	162	193	236	266			
V	11	159	195	230	263	282		
VI	2	144	204	232	256	279	300	
VII	2	165	189	250	280	306	327	352
Weighted mean		153	195	234	266	289	313	352

Table 2. Growth (mm) comparisons of largemouth bass from different lakes in Arkansas.

Locality and reference	1	2	3	4	5	6	7	8	9	10
Lake Elmdale (Present study)	153	195	234	266	289	313	352			
Lake Fort Smith (Olmsted, 1974)	149	243	307	360	394	445	452			
Crystal Lake (Kilambi et al., 1978)	100	198	259	300	335	373	403	424	455	484
Beaver Reservoir (Bryant and Houser, 1971)	152	277	333	396	462	474				
Bull Shoals Reservoir (Bryant and Houser, 1971)	176	297	277	427	457	492	519	524		

Table 3. Comparison of largemouth bass population density among five Arkansas lakes.

Lake and reference	Shoreline (Km)	Population density (n/Km)
Lake Elmdale (Present study)	5.8	1541
Crystal Lake (Kilambi et al., 1976)	4.2	756
Beaver Reservoir (Bryant and Houser, 1971)	723	323
Bull Shoals Reservoir* (Bryant and Houser, 1971)	1,192	199
Lake Fort Smith (Olmsted, 1974)	11.8	120

*Petersen estimate

Table 4. Comparison of largemouth bass standing crop among 3 Arkansas lakes.

Lake and reference	Standing crop (kg/ha)
Lake Elmdale (Present study)	30.4
Beaver Reservoir (Bryant and Houser, 1971)	10.8
Bull Shoals Reservoir (Bryant and Houser, 1971)	5.6

less than 150 mm comprised 47% of the total number of bass collected, and bass less 250 mm in length were responsible for a standing crop of 23.4 kg/ha of the total 30.4 kg/ha. Lake Elmdale then has a predominance of small bass which probably feed heavily on entromostracans (Applegate et al., 1966; Goodson, 1965; Ridenhour, 1960; Olmsted, 1974). Also, studies have shown that fish production is directly related to plankton production (Hooper, 1975). The high bass population density of Lake Elmdale was attributable to survival of young bass due to availability of zooplankton.

CONCLUSIONS

Lake Elmdale largemouth bass have the highest population density and lowest growth rate of five Arkansas lakes. The standing crop of the lake is higher than that of two other Arkansas lakes with 77% of the weight composed of fish less than 250 mm. Lake Elmdale is a good example that fertilization will increase the yield of fish in a lake, but the increased production led to more small fish which caused an increased density that probably caused the lowered growth rate. It would appear that management measures should be taken to decrease the inorganic fertilization and prevent the runoff from the poultry industry. Then the largemouth bass population can be monitored for signs of improved growth.

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GENERAL NOTES

CONCENTRATIONS OF TOTAL DISSOLVED SOLIDS AND SELECTED CATIONS IN DARDANELLE LAKE, ARKANSAS

One indicator of water quality is the amount of ionic compounds dissolved in the water. This can be measured indirectly by determining the total dissolved solid (TDS), the great bulk of which is ionic. TDS is an important criterion for the quality of irrigation water.

Although salts present in irrigation water provide some nutrients essential to plants, excessive salt concentration inhibits plant growth. Excessive Na^+ replaces Ca^{2+} and Mg^{2+} in the soil thus strongly influencing the physical properties and plant nutritional capabilities of the soil.

High salinity in drinking water presents very little health hazard, limited to minor and temporary disturbance of the digestive system.

In 1972 and again in 1973, personnel of the Arkansas Department of Pollution Control and Ecology measured, among a large number of variables, TDS in the Arkansas River (Water pollution control survey of the Arkansas River Basin, Arkansas Department of Pollution and Ecology, Water Division, 1,233 pp, 1974). In 1972, the average value of TDS was 482 mg/l for the period from August to October; in 1973, the average value was 377 mg/l but for the period June - August. The water of 1972 was classified as having a high salinity hazard and a medium sodium hazard as irrigation water. But, it was concluded that since the concentration of salt and the TDS had decreased, the quality of the water had improved from 1972 to 1973. The survey states, "Now the river meets the U. S. Public Health Service drinking water standard of 500 ppm dissolved solids even during periods of low flow."

Actually this decrease probably was due to the different collection times, since there is a very definite seasonal variation in TDS in the Arkansas River. Since 1973, values of TDS in the period August - October have increased. As a part of a study of the radioactivity in the Dardanelle Lake section of the Arkansas River (Chittenden, Radionuclides in the Arkansas River upstream and downstream from the Nuclear I power generating facility, 27 pp., 1978), the total dissolved solids were measured in the process of determining the gross beta activity of the water. TDS is defined, in this work, as the material in solution or suspension which will pass through Whatman 42 filter paper.

The TDS was determined by evaporating a 100-500 ml aliquot of water that had been filtered through Whatman 42 paper. The residue was quantitatively transferred to a stainless steel counting planchet and dried to constant weight at 105°C.

The Na^+ and K^+ concentrations were determined by flame emission spectroscopy using a Jarrell-Ash Dial Atom A. A. Spectrometer. The hardness was determined by the standard EDTA titration.

Figure 1 summarizes the variation in the mass of dissolved solids per liter of water collected from the surface at the dam (Station 4). Samples from both Stations 3 and 4 are typical of Arkansas River water, but more data is available for TDS at Station 4. TDS varied widely during 1976, rising to a maximum in June, falling, and then rising to a second, lower and broader maximum in autumn. The June maximum appeared again in 1977. Since the project ended in September, 1977, it is not known if the autumn maximum also appeared in 1977.

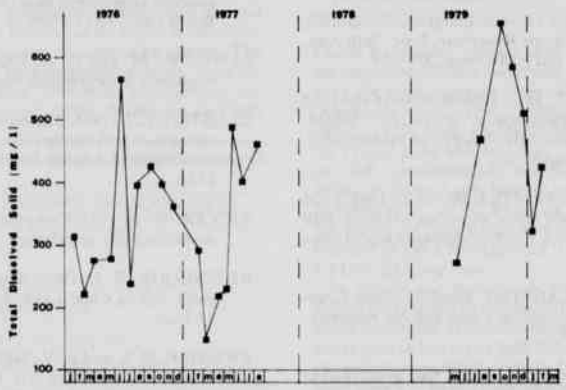

Figure 1. Total dissolved solids (TDS) distribution for water at the dam (Station 4).

The study was resumed in May, 1979, and monthly sampling was begun in October. The autumn maximum is quite pronounced. Unfortunately sampling was not done in June or July, so the summer maximum for 1979 is not known. Since May, 1979, The Na^+ concentration has varied from 46 ppm (in January, 1980) to 140 ppm (in October, 1979); total hardness (Ca^{2+} and Mg^{2+}, expressed as Ca^{2+}) ranged from 36 ppm to 62 ppm, for the same months; the range of K^+ was 1.5-2.6 ppm. The variation of these concentrations followed that of TDS quite closely.

These trends are quite similar to those exhibited by the surface water of the Lake Powell section of the Colorado River (Johnson and Merritt, Water Resources Res., 15:873-884, 1979). The Colorado River is used as a comparison because it also carries a substantial load of dissolved material. A plot of the seasonal variation of TDS in Lake Powell also exhibits two maxima, the more pronounced being the earlier of the two.

Dissimilarities are also evident. In Lake Powell, the more pronounced maximum in TDS usually occurs in the spring rather than June, and the autumn maximum is barely noticeable, but it does exist. In the Colorado River, TDS varies only slightly during the year, 500-600 mg/l at the surface and 600-700 mg/l in subsurface water. This TDS remained fairly constant over a three year interval. The TDS of the Arkansas River shows much wider variation (240-540 mg/l in 1976).

It also should be noticed that the TDS is markedly higher in the late summer of 1979 than in the late summers of 1976 or 1977. If the wide autumn maximum in 1977 was similar (in the geometrical sense of the word) to that of 1976, the average TDS in 1977 would have been greater than in 1976 despite lower values during the first half of 1977. The average value of TDS in 1979 can be assumed to be higher still since each monthly value measured was greater than or equal to the corresponding values of 1976 and 1977. If there is, indeed, such a trend, the quality of water in the Arkansas River is seriously deteriorating.

In the Colorado River of the early 1950's, before the system of dams was completed, the TDS did vary over a wide range, 400-1200 mg/l, during the year, but the minimum occurred during the summer, corresponding to a maximum in the volume of water passing along the river. There seems to be no such correspondence in the Arkansas [see (Chittenden, Proc. Ark. Acad. Sci., 33:25-27, 1979) for the discharge at the dam for most of the 1976-1977 period].

The average concentration of Na^+, K^+, and total hardness in the world's rivers has been estimated (Livingstone, D. A. 1963. Chemical composition of rivers and lakes. U. S. Geol. Surv. Prof. Paper 440-G, U. S. Government Printing Office, Washington, D. C., 64 pp.) to be respectively, 6.3, ppm, 2.3 ppm, and 21.8 ppm. In the Arkansas River, only the K^+ is "normal", Na^+ ranges from 6-23 times the average and total hardness from 1.5-3 times the average.

The maximum in June may be connected with preparation of agriculture land for planting and with the volume of spring precipitation. The marked maximum in autumn may be connected with the disturbance of the soil at the end of the agricultural growing season. Intensive agricultural activity and irrigation may be causing an increase in the already high salinity in the waters of the Arkansas River.

Further measurements over the next eighteen months should further elucidate the trend in the variation of the TDS. If this trend is a monotonic increase, the problem of water quality in the Arkansas River will be as serious as that in the Colorado River.

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FACTORS AFFECTING THE Sr-90 CONCENTRATION IN DARDANELLE LAKE, ARKANSAS

Variations in the Sr-90 concentration and in the amount of $Ca^{2+} + Mg^{2+}$ present in the water of Dardanelle Lake seem to be related in samples collected near the outlet for reactor cooling water (Station 1) and at the dam (Station 4). This dependence was first noticed as a variation of Sr-90 activity with total dissolved solids (TDS). Most of the Sr-90 released by the reactor leaves the lake in solution but some remains behind in the form of ions adsorbed on the surface of sediment particles.

The release of this adsorbed Sr-90 is postulated to be an ion-exchange type of process:

$$Ca^{2+} + {}^{90}Sr^{2+}\_\_\_\_\_\text{sediment} \rightleftharpoons {}^{90}Sr^{2+} + Ca^{2+}\_\_\_\_\_\text{sediment}$$

The concentration of Sr-90 activity can be expressed as:

$$A_{90} = B_0 + B_1(A_r) + B_2(C) \quad (1)$$

where A_{90} = the concentration of Sr-90 activity (pCi/l) in lake water
A_r = the concentration of all the activity released by the reactor (pCi/l)
C = the concentration of $Ca^{2+} + Mg^{2+}$ (ppm)
B_0 = Sr-90 from fallout present in lake water (pCi/l)
B_1, B_2 = constant coefficients

For studies prior to 1979 (Chittenden, Radionuclides in the Arkansas River, upstream and downstream from the Nuclear I power generating facility, 27 pp, 1978.) only the TDS values were determined. It was found that the concentration of $Ca^{2+} + Mg^{2+}$ was a fairly constant $(10 \pm 1)\%$ of TDS. Thus

$$C = (0.10 \pm 0.01)(\text{TDS}) \quad (2)$$

Combining equations (1) and (2),

$$A_{90} = B_0 + B_1(A_r) + B_3(\text{TDS}) \quad (3)$$

where $B_3 = B_2(0.10 \pm 0.01)$

The data for the individual collecting stations (Chittenden and McFadden, Proc. Ark. Acad. Sci. 32:31-34, 1978.) were treated statistically using the MINITAB package available on the Harris/7 system at Arkansas State University. Regression analyses were used to derive the coefficients for equation (3) and correlation coefficients were calcuated for Sr-90 activity and TDS. Table 1 summarizes these values.

Table 1. Results of Statistical Analysis of Data

Station	1	2	3	4
Location	Downstream	Upstream	Upstream	Downstream
Amount of Sr-90 Adsorbed	High	Low	Low	Moderate
B_0	0.45	0.63	0.91	0.56
B_1	0.00	0.067	0.00	0.048
B_3	9.2E-4	0.0E-4	0.0E-4	3.4E-4
r	0.82	0.06	0.00	0.45

Note: $9.2E-4 = 9.2 \times 10^{-4}$

There is no correlation between Sr-90 activity and TDS at the upriver stations (2 and 3), where there should be no appreciable amounts of Sr-90 adsorbed on the sediment. At Station 1, where the highest concentrations of adsorbed Sr-90 would be expected, the correlation is quite good. At Station 4, approximately two miles downriver from the reactor where there may be some deposition of suspended sediment, the correlation is modest.

Preliminary data gathered since August, 1979, indicates that the correlation coefficient of Sr-90 activity with total hardness ($Ca^{2+} + Mg^{2+}$) is >0.9 at Station 1.

Thus, it seems likely that the release of Sr-90 adsorbed on sediment is a significant source of that radionuclide in water downstream from the reactor.

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THE USE OF A CALCULATOR CHIP FOR REALTIME DATA PROCESSING

The problem of collecting data in a digital form ordinarily might be handled by dedicating a microprocessor system to the task of collecting the data from the sensor, processing that data and finally outputting the data in an intelligible form. However, the power of a microprocessor system may be a case of "overkill' if it is to be dedicated to one or more relatively slow speed tasks. In place of a microprocessor system, one may find that a low cost calculator chip such as found in readily available four function calculators can provide the computing power along with a degree of programability necessary to carry out the required tasks for a small processing system.

The problem of interest here is to design a digital system which measures rate of fluid flow, elapsed time and total travel distance. A calculator chip is used to process and display total volume, rate of flow, total distance and elapsed time. The data are displayed by (seven segment), L.E.D.'s. The particular data displayed are switch selected by the operator.

The circuit (Fig. 1) consists of five principle blocks, numbered 1 through 5 for discussion. The time base for the circuit, (block 1), a 555 timer wired as a bistable multivibrator, drives a series of J-K flip-flops and gates to produce a nonoverlapping two-phase clock output, (after Heathkit Digital Techniques, 1975, page 7-99). The phase one, (1), increments a counter which addresses the program stack while the second clock phase, (2), drives the multiplexer that carries out the instructions stored in the stack.

A 3-input nand gate stops the clocking of the J-K flip-flops when a stack instruction commands it. This feature is useful for extended periods of data collection.

The memory, (block 2), contains the program stack and is sequentially addressed by the 6-bit counter mentioned earlier. The program stack consists of 4-bit commands sent in parallel to two tri-state buffers, (blocks 3 and 4). The buffers direct the 4-bit control information to one of two multiplexers; these multiplexers carry out the instructions provided by the 4-bit control code by activating one of sixteen output lines of the multiplexers.

Switches, (block 2), are used to program the stack. Switches A through D provide the 4-bit code which is loaded by switch W. E. at a location provided by the stack pointer. The stack pointer is incremented by switch INC: switch RST is the resent switch which initializes the stack pointer, (address 000000).

The tri-state buffers, (blocks 3 and 4), are activated by the outputs Q; Q of a J-K flip-flop. This provides an alternate activation scheme for the buffers insuring only one is active at a given instant.

The 4-bit stack commands are normally channeled through the buffer of block 4 to the multiplexer contained therein. This addresses one of the 16 mutually exclusive lines of the multiplexer whenever the two clock pulse is low. The activated line performs the specific function wired to it, (e.g., register shift, data clear, latch enable, or multiply, etc.). The multiplexer interfaces to the calculator chip, (block 5), through PNP transistors acting as on-off switches.

The block 3 buffer is used for direct entry of program constants to the calculator chip. These constants are used in the data processing stage of the function. Data are entered by reversing the states of the two buffers. Once data are entered, the buffers are returned to their normal state.

With the buffers in their normal state, data are entered from the counters via a tri-state data selector. The selector enable and selection lines are both driven by the multiplexer of block 4. The counters are each 3-digit decade counters with an internal left circulating shift register, which determines which digit is displayed at the output line. The chips may be latched, reset and selected independently, so that data entry is not interrupted during chip selection.

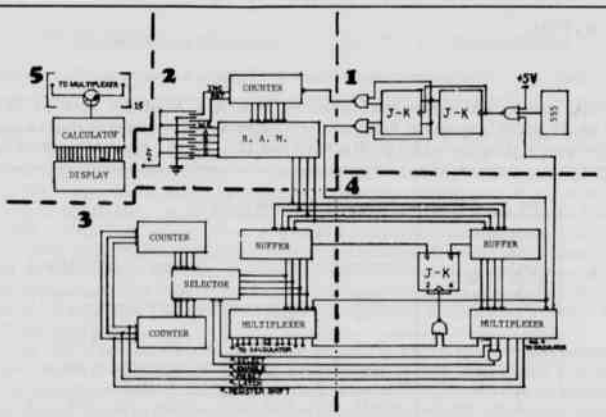

Figure 1. Schematic interface circuit. Lines Inc., RST. W.E. and A-D (block 2) are on-off switches.

In this particular application, the calculator chip along with its associated display circuitry was used to perform required mathematical manipulation and to drive the L.E.D. display.

The application discussed here is only one of the large variety of applications in which a limited computing and control capability is useful. One might consider the use of a calculator chip in place of a microprocessor whenever the application requires principally the calculating power of the chip rather than the control power inherent in a microprocessor system. As a bonus the display driving capabilities are available for outputting the processed information. The display output also may be used for control purposes if desired.

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REMNANT PRAIRIE IN FAULKNER COUNTY, ARKANSAS?

Before white man came to Arkansas, several areas of the state supported large tallgrass ecosystems. The largest of these was the Grand Prairie, located north of the lower half of the Arkansas River; in other parts of the state smaller prairies existed. The Grand Prairie is estimated to have covered one-half to three-quarters of a million acres well past 1900 (Arkansas Department of Planning, Arkansas Natural Area Plan, Little Rock, 247 pp., 1974; Irving and Brenholts, An Ecological Reconnaissance of the Roth and Konecny Prairies, Arkansas Natural Heritage Commission, 50 pp., 1977). Today, the tallgrass prairie remnants can be found in Arkansas counties designated in Figure 1. No prairie remnants have been documented in Faulkner County. This major, distinct ecosystem largely has disappeared from the landscape due to cultivation and other activities of man, so much so that it has become important to identify any remaining prairie of high quality for preservation.

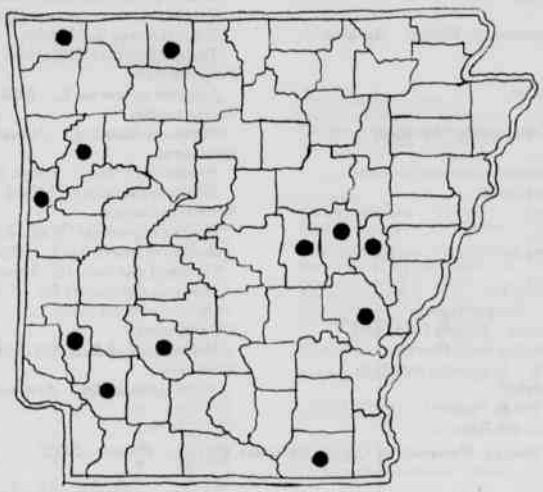

Figure 1. Arkansas counties where there are extant, tallgrass prairie remnants.

On the southern edge of Conway adjacent to industrial development lies an 18-20 acre open field owned by Frank Henze where a large population of *Castilleja coccinea* flowers each spring. *C. coccinea* is a species that typifies remnant areas of prairie in Arkansas (Ark. Dept. of Planning, 1974); this species should be considered rare and endangered in the state. According to the owner, several acres of the Henze property being studied have not been under cultivation for at least 40 years; the sole maintenance of this land has been an annual, fall mowing for hay. A number of collection trips were made to the Henze property between mid-April and early November, 1979. Plants were collected, processed and filed in the University of Central Arkansas Vascular Plant Herbarium. Since the central portion of this field has been cultivated, plants from the obviously disturbed areas were not collected.

Plants that are commonly found in and indicative of areas of remnant prairie (Ark. Dept. of Planning, 1974; Irving and Brenholts, 1977; Weaver, North American Prairie, 348 pp., 1954; Bill Shepard, *pers. comm.*) that were collected from the Henze prairie are: *Andropogon ternarius*, Split-Beard Bluestem; *Andropogon gerardi*, Big Bluestem; *Andropogon virginicus*, Broomsedge; *Sorghastrum avenaceum*, Indian Grass; *Liatris pycnostachya*, Blazing Star; *Eryngium yuccifolium*, Rattlesnake Master; *Buchnera americana*, Blue Hearts; and *Castilleja coccinea*, Indian Paintbrush (see List of Species Collected). Weaver (1954) indicates that the presence of Big Bluestem and Indian Grass (which are found on the Henze property) suggests that a piece of land is a remnant of the tallgrass prairie which grew in areas that were more moist. He further suggests that Little Bluestem *(Andropogon scoparius)* is usually found on better drained soils, which may help account for its absence on the Henze property. The annual fall mowing for hay may also retard or eliminate such expected species. A number of species were likely present but not collected due to staggered collecting trips. Should this field be remnant prairie, it does not appear to be in prime condition (Bill Shepard, *pers. comm.*).

LIST OF SPECIES COLLECTED (Nomenclature is largely in accordance with Smith, An Atlas and Annotated List of Vascular Plants of Arkansas, University of Arkansas at Fayetteville, 592 pp., 1978.)

Apiaceae
Eryngium yuccifolium Michx. Rattlesnake Master
Asclepiadaceae
Asclepias hirtella (Pennell) Woodson Milkweed
Asteraceae
Aster pilosus Willd. White Heath Aster
Boltonia diffusa Ell.
Coreopsis tinctoria Nutt. Tickseed
Eupatorium rotundifolium L.
Helianthus angustifolius L. Sunflower
Heterotheca graminifolia (Michx.) Shinners Grass-leaved Golden Aster
Hieracium longipilum Torr.
Lactuca canadensis L. Wild Lettuce
Liatris pycnostachya Michx. Blazing Star
Pyrrhopappus carolinianus (Walt.) D. C. False Dandelion
Rudbeckia hirta L. Black-eyed Susan
Senecio tomentosus Michx.
Solidago canadensis L. Goldenrod
Solidago leptocephala T. & G. Goldenrod
Solidago nemoralis Ait. Old Field Goldenrod
Solidago rugosa Ait. Rough-leaved Goldenrod
Vernonia missurica Raf. Ironweed
Campanulaceae
Lobelia puberula Michx. var. *mineolana* E. Wimm. Big Blue Lobelia
Convolvulaceae
Cuscuta cuspidata Engelm. Dodder
Cyperaceae
Cyperus ovularis (Michx.) Torr. Hedgehog Club Rush
Cyperus strigosus L.
Eleocharis tenuis (Willd.) Schultes var. *verrucosa* Svenson
Rhynchospora globularis (Chapm.) Small
Euphorbiaceae
Crotonopsis elliptica Willd.
Euphorbia corollata L. Flowering Spurge
Fabaceae
Cassia fasciculata Michx. Partridge Pea
Desmodium ciliare (Muhl.) D. C. Begger's Lice
Lespedeza cuneata (Dumont) G. Don Sericea Lespedeza
Lespedeza repens (L.) Bart. Creeping Bush Clover
Lespedeza striata (Thunb.) H. & A. Japanese Lespedeza
Strophostyles umbellata (Willd.) Britt.
Stylosanthes biflora (L.) B.S.P. Pencil Flower
Tephrosia virginiana (L.) Pers. Goat's Rue
Hypericaceae
Hypericum drummondii (Grev. & Hook.) T. & G. Nits-and-lice
Juncaceae
Juncus marginatus Rostk.
Lamiaceae
Prunella vulgaris L. Self-heal
Pycnanthemum muticum (Michx.) Pers. Mountain Mint
Pycnanthemum tenuifolium Schrad. Slender Mountain Mint
Melastomataceae
Rhexia mariana L. Meadow Beauty
Orchidaceae
Spiranthes cernua (L.) Richard Common Ladies' Tresses
Plantaginaceae
Plantago virginica L. Hoary Plantain
Poaceae
Andropogon gerardi Vitman Big Bluestem
Andropogon ternarius Michx. Split-beard Bluestem
Andropogon virginicus L. Broomsedge
Panicum anceps Michx. Beaked Panicum
Panicum scoparium Lam. Velvet Panic
Paspalum floridanum Michx. Florida Paspalum
Paspalum laeve Michx. Field Paspalum
Setaria geniculata (Lam.) Beauv. Knotroot Bristlegrass
Sorghastrum avenaceum (Michx.) Nash Indian Grass
Tridens flavus (L.) Hitchc. Purpletop
Tridens strictus (Nutt.) Nash Longspike Tridens
Polygalaceae
Polygala sanguinea L. Milkwort
Polygonaceae
Rumex acetosella L. Sheep Sorrel
Rubiaceae
Diodia teres Walt. Rough Buttonweed
Hedyotis caerulea (L.) Hook Bluets
Scrophulariaceae
Bacopa acuminata (Walt.) Robins. Water Hyssop
Buchnera americana L. Blue Hearts
Castilleja coccinea (L.) Spreng. Indian Paintbrush
Gerardia fasciculata Ell. Gerardia
Gerardia viridis Small
Valerianaceae
Valerianella radiata (L.) Dufr. Corn Salad
Violaceae
Viola sagittata Ait. Arrow-leaved Violet

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A CONTINUATION OF SPIDER RESEARCH IN ARKANSAS: GULF COASTAL PLAINS

For the past 13 years, research has been pursued concerning the spider fauna of Arkansas. At the present time, 233 species of spiders have been reported for Arkansas by Dorris (1972, 1977). This study revealed 235 species, 14 of which were new for the state. This is the second of a series of studies which will include a total of six areas: Ozark Mountains, Arkansas River Valley, Ouachita Mountains, Gulf Coastal Plain, Delta, and Crowleys Ridge. The first, included the Ouachita Mountain Area (Dorris, 1977), and this paper presents the spider fauna of the Gulf Coastal Plains Area of Arkansas (Fig. 1). Eventually, when all areas are covered, the spider fauna of the entire state of Arkansas can be ascertained with relation to distribution.

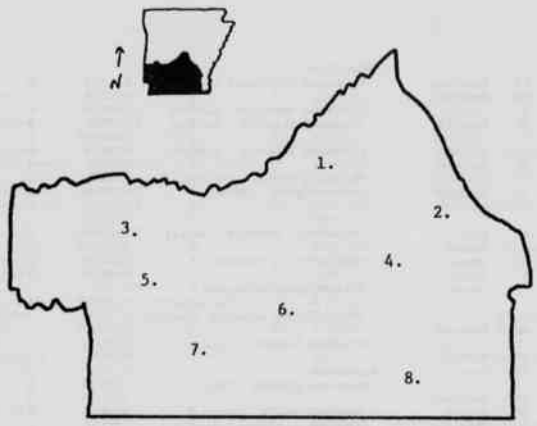
Methods of collecting used in the Gulf Coastal Plains Area were the same as those used in the Ouachita Mountain Area (Dorris, 1977): (a) heavy duty sweep net to sweep grasses and heavy brush; (b) sieve to sift leaf litter; (c) hatchet for chopping bark off trees; (d) hand picking from bushes, ground and old dwellings or other places; (3) mud-dauber nest collections to reveal paralyzed spiders captured by mud-daubers; and (f) night spot-lighting.

The spiders collected were placed in screw cap bottles with 70% ethyl alcohol. A field book was kept to identify bottle numbers and check stations and to record other pertinent data.

For complete coverage of the Gulf Coastal Plains, check stations were established in the eastern, central, and western sections of the area (Fig. 1). These check stations were covered from July, 1978 through December, 1979 using all collecting methods. Each station was checked three or more times to insure complete coverage.

Names used are those employed by Comstock (1948), Kaston and Kaston (1953), and Gertsch (1949). The arrangement of specimens examined is that of Kaston and Kaston (1953).

General Notes



1. Donaldson, Hot Spring County
2. Randall, Cleveland County
3. Columbus, Hempstead County
4. Fordyce, Dallas County
5. Fulton, Hempstead County
6. White Oak Lake, Ouachita County
7. Garland City, Miller County
8. El Dorado, Union County

Figure 1. Map of West Gulf Coastal Plains Showing Check Stations

Specimens Examined

Taxon	Date Collected	Station Codes	Collecting Codes	Habitat
Theraphosidae				
Dugesiella hentzi Walckenaer	10/12/78	1	P	Roadside
	10/25/79	7	P	Roadside
	11/18/79	5	P	Roadside
Oecobiidae				
Oecobius cellariorum Duges	11/7/79	2	S	Forest
	12/10/79	8	SN	Forest
Scytodidae				
Scytodes thoracica (Latrielle)	7/14/78	1	P	Building
	10/12/78	2	P	Building
	12/4/78	3	P	Building
	4/11/79	4	P	Building
	6/18/79	7	P	Building
Loxosceles reclusa Gertsch & Mulaik	8/10/78	1	P	Building
	9/16/78	4	P	Building
	10/11/79	6	P	Building
	12/3/79	8	P	Building
Filistatidae				
Filistata hibernalis (Hentz)	5/7/78	1	P	Building
	7/15/78	3	P	Building
	9/11/78	5	P	Building
	6/12/79	6	P	Building
	7/15/79	7	P	Building
	8/24/79	8	P	Building
Amaurobiidae				
**Amaurobius bennetti* (Blackwall)	5/7/78	1	SN	Roadside
**Callioplus tibialis* (Emerton)	11/18/79	7	SN	Roadside
Titanoeca americana Emerton	8/28/79	1	S	Forest
	11/7/79	8	S	Forest
Dysderidae				
**Ariadna bicolor* (Hentz)	11/18/79	7	SN	Roadside
Lycosanidae				
Lycosomines viridis Hentz	10/25/79	7	SN	Roadside
Ctenizidae				
Ummidia audouini (Lucas)	10/12/78	1	SN	Roadside
	12/10/78	2	SN	Roadside
	7/15/78	3	SN	Roadside
	9/16/78	4	SN	Roadside
	8/24/79	8	SN	Roadside
Pholcidae				
Pholcus phalangioides (Fuesslin)	6/10/78	4	P	Building
	7/15/79	7	P	Building
	9/24/79	8	P	Building
Uloboridae				
Hyptiotes cavatus (Hentz)	10/25/79	5	P	Building
	11/16/79	7	P	Building
Uloborus americanus Walckenaer	10/25/79	5	P	Building
	11/16/79	7	P	Building
	6/10/78	4	P	Building
Dictynidae				
Dictyna subtata (Hentz)	11/18/79	7	S	Forest
Dictyna volucripes Keyserling	10/25/79	5	S	Forest
Dictyna annulipes (Blackwall)	10/12/78	1	S	Forest
Dictyna segregata Gertsch & Mulaik	11/18/79	7	S	Forest
	11/7/79	8	S	Forest
Gnaphosidae				
Cesonia bilineata (Hentz)	12/10/78	2	SN	Roadside
Herpyllus vasifer (Walckenaer)	7/15/78	3	SN	Forest
	6/12/79	6	SN	Roadside
Drassodes neglectus (Keyserling)	8/18/78	3	SN	Roadside
Rachodrassus echinus Chamberlin	6/10/78	4	SN	Forest
Drassylus covensis Exline	8/24/79	8	SN	Roadside
Drassylus mephisto Chambers	11/18/79	7	SN	Roadside
Drassylus fallens Chambers	12/10/78	2	SN	Roadside
Drassylus creotus Chambers & Gertsch	5/7/78	1	SN	Roadside
Sergiolus capulatus (Walckenaer)	6/25/78	3	SN	Roadside
	7/10/79	7	SN	Roadside
Gnaphosa sericata (L. Koch)	5/27/78	2	SN	Roadside
	5/30/79	6	SN	Roadside
Zelotes hentzi Barrows	5/27/78	2	SN	Roadside
Callilepis imbecilla (Keyserling)	6/10/79	8	SN	Roadside
Clubionidae				
Chiracanthium inclusum (Hentz)	4/11/78	4	SN	Roadside
	6/15/79	7	SN	Roadside
	11/24/79	8	SN	Roadside
Castianeira descripta (Hentz)	11/24/79	8	SN	Forest
**Castianeira gertschi* Kaston	6/15/79	7	SN	Roadside
Clubionidae				
**Castianeira cingulata* Koch	7/15/78	3	SN	Roadside
Castianeira vulnerea Gertsch	4/11/78	4	SN	Roadside
**Castianeira amoena* (Koch)	7/15/78	3	SN	Roadside
Castianeira longipalpus (Hentz)	11/18/79	7	SN	Roadside
Clubiona obesa Hentz	8/10/78	1	SN	Roadside
	9/16/78	4	SN	Roadside
	10/11/79	6	SN	Roadside
Clubiona abbotii Koch	6/25/78	3	SN	Roadside
	7/10/79	7	SN	Roadside
	5/30/79	6	SN	Roadside
**Clubiona riparia* Koch	6/15/79	7	SN	Roadside
Clubiona excepta Koch	10/15/78	7	SN	Roadside
Clubiona moesta Banks	10/15/78	7	SN	Roadside
Agroeca pratensis (Emerton)	7/15/78	3	SN	Roadside
	9/11/78	5	SN	Roadside
Marcellina piscatoria (Hentz)	12/10/78	2	SN	Roadside
Trachelas tranquillus (Hentz)	9/16/78	4	SN	Roadside
	8/24/79	8	SN	Forest
Trachelas taticeps Bryant	5/30/79	6	SN	Roadside
Micaria aurata (Hentz)	7/15/78	3	SN	Roadside
Meriola decepta Banks	8/10/78	1	SN	Roadside
Scotinella formica (Banks)	6/18/79	7	SN	Forest

Anyphaenidae				
Anyphaenella saltibunda (Hentz)	6/15/79	7	SN	Roadside
Phrurotimpus borealis (Emerton)	8/24/79	7	SN	Roadside
Aysha gracilis (Hentz)	12/10/78	2	S	Forest
	10/11/79	6	SN	Roadside
	12/10/78	2	P	Building
Anyphaena maculata Banks	12/10/78	2	SN	Roadside
Anyphaena celer (Hentz)	3/15/78	3	SN	Roadside
	5/18/79	4	SN	Roadside
Anyphaena fragilis Banks	5/18/79	4	SN	Roadside
Ctenidae				
**Anahita animosa* (Walckenaer)	5/18/79	4	S	Forest
	12/3/79	8	S	Forest
Libitiodes sayi (Hentz)	12/10/78	2	S	Forest
**Zora pumila* (Hentz)	10/12/78	1	S	Forest
Ctenus hibernalis (Hentz)	4/11/79	4	SN	Forest
Thomisidae				
**Coriarachne lenta* (Walckenaer)	6/10/78	4	SN	Roadside
Coriarachne vericolor Keyserling	6/10/78	4	SN	Roadside
	5/30/79	6	SN	Roadside
Misumenoides formosipes (Walckenaer)	8/10/78	1	SN	Roadside
	9/16/78	4	SN	Forest
	10/11/79	6	SN	Roadside
	12/3/79	8	SN	Forest
Misumenops celer (Hentz)	5/7/78	1	SN	Roadside
Misumenops asperatus (Hentz)	5/7/78	1	P	Building
	9/16/78	4	SN	Roadside
	8/24/79	8	SN	Roadside
Misumenops oblongus Keyserling	12/10/78	2	SN	Roadside
Xysticus elegans Keyserling	10/12/78	2	SN	Roadside
	6/18/79	3	P	Building
	8/24/79	4	SN	Forest
Xysticus ferox (Hentz)	5/27/78	2	SN	Roadside
	12/4/78	3	SN	Roadside
	8/24/79	8	SN	Roadside
Xysticus triguttatus Keyserling	5/30/79	3	SN	Roadside
	9/16/78	4	SN	Roadside
Xysticus tumefactus (Walckenaer)	10/25/79	5	P	Roadside
Xysticus gulosus Keyserling	9/11/78	5	SN	Roadside
	11/18/79	7	SN	Roadside
Xysticus texanus (Banks)	6/30/78	5	SN	Roadside
Xysticus funestus Keyserling	6/12/79	6	SN	Roadside
	10/25/79	5	SN	Roadside
Xysticus autificus Keyserling	10/11/79	6	P	Roadside
Xysticus nervosus (Emerton)	5/7/78	1	SN	Forest
	7/15/78	3	P	Forest
Xysticus transversatus (Walckenaer)	5/30/79	6	SN	Roadside
Tibellus oblongus (Walckenaer)	5/18/78	7	SN	Roadside
	10/25/79	5	P	Building
Synema parvula (Hentz)	7/14/78	1	P	Building
	12/4/78	3	SN	Roadside
	8/24/79	8	SN	Roadside
Philodromus keyserlingi Marx	7/14/78	1	SN	Roadside
Philodromus pernix Blackwall	6/30/78	6	SN	Roadside
	7/25/79	4	SN	Roadside
Philodromus abbotii Walckenaer	4/13/78	3	SN	Forest
	6/30/78	6	SN	Roadside
Philodromus imbecillus Keyserling	5/27/78	8	SN	Roadside
	7/25/79	7	P	Roadside
Philodromus rufus Walckenaer	10/15/78	1	SN	Roadside
	7/15/79	2	SN	Roadside
	7/25/79	4	SN	Roadside
	10/18/79	5	SN	Roadside
Philodromus marxii Keyserling	4/13/78	3	SN	Roadside
Philodromus vulgaris Keyserling	7/15/79	2	SN	Roadside
	10/18/79	5	SN	Roadside
Ebo latithorax Keyserling	10/15/78	1	P	Roadside
	7/25/79	7	P	Forest
Oxyptila conspurcata Thorell	5/27/78	8	SN	Roadside
Thanatus formicinus (Clerck)	10/18/79	5	SN	Roadside
Tibellus oblongus (Walckenaer)	4/13/78	3	SN	Roadside
	7/15/79	2	P	Forest
Tmarus angulatus (Walckenaer)	6/30/78	6	SN	Roadside
Salticidae				
**Phidippus otiosus* Peckham	10/18/79	5	P	Forest
Phidippus audax (Hentz)	10/15/78	1	P	Building
	7/15/79	2	P	Building
	4/13/78	3	P	Building
	10/18/79	5	P	Building
	7/25/79	4	P	Building
	6/30/78	6	P	Building
	7/25/79	7	P	Building
	5/27/78	8	P	Building
Phidippus whitmani Peckham	10/15/78	1	SN	Roadside
	4/13/78	3	P	Building
Phidippus insignarius (C.L. Koch)	10/18/79	5	SN	Roadside
Phidippus insolens Peckham	5/27/78	8	P	Building
Phidippus carolinensis Peckham & Peckham	4/13/78	3	SN	Roadside

Thomisidae				
Phidippus purpuratus Keyserling	6/30/78	6	SN	Roadside
	4/13/78	3	P	Forest
Phidippus mystaceus Emerton	7/25/79	4	P	Forest
Phidippus princeps Peckham	5/27/78	8	P	Building
	10/18/79	5	P	Forest
Phidippus putnami Peckham	6/30/78	6	SN	Roadside
	7/25/79	4	SN	Roadside
Phidippus clarus Keyserling	4/13/78	3	P	Forest
Icius elegans (Hentz)	5/27/78	8	P	Building
	7/25/79	7	P	Forest
	7/15/79	4	SN	Roadside
Habronattus borealis (Banks)	10/15/78	1	SN	Roadside
	10/18/79	1	SN	Roadside
Neon nelli Peckham	5/27/78	8	SN	Roadside
	4/13/78	3	P	Forest
Paraphidippus marginatus (Walckenaer)	10/15/78	1	SN	Forest
Paraphidippus aurantius (Easton)	7/25/79	7	P	Roadside
	10/18/79	5	P	Forest
**Marpissa lineata* (Koch)	6/30/78	6	SN	Roadside
Salticidae				
**Marpissa lineata* (Koch)	7/25/79	4	SN	Forest
	7/15/79	2	MD	Building
Marpissa undata (DeGeer)	4/13/78	3	SN	Roadside
**Sassacus papenhoei* Peckham	7/15/79	2	SN	Roadside
	10/18/79	5	SN	Roadside
Metaphidippus galathea (Walckenaer)	10/18/79	5	SN	Roadside
	10/15/78	1	SN	Forest
Metaphidippus flavipedes (Peckham)	10/12/78	1	SN	Roadside
Metaphidippus protervus (Walckenaer)	11/18/79	7	SN	Roadside
Metaphidippus insignis (Banks)	11/7/79	8	SN	Forest
Metaphidippus canadensis (Banks)	10/12/78	2	SN	Roadside
Thiodina sylvana (Hentz)	4/11/79	4	SN	Roadside
	6/18/79	7	P	Building
Zygoballus bettini Peckham	10/12/78	2	SN	Roadside
	11/7/79	8	P	Roadside
	6/18/79	7	SN	Roadside
Zygoballus sexpunctatus (Hentz)	6/30/78	6	SN	Forest
Eris pineus (Easton)	7/25/79	4	P	Forest
Agassa cyanea	7/15/79	2	P	Roadside
	7/25/79	4	SN	Roadside
Metacyrba taeniola (Hentz)	10/18/79	5	SN	Roadside
Gyrmarachne hentzi Banks	7/15/79	2	SN	Roadside
Ballus youngii Peckham	12/10/78	2	SN	Roadside
	11/7/79	8	P	Roadside
Habronattus coronatus (Hentz)	7/14/78	1	SN	Roadside
Plexippus paykerpeus Emerton	10/25/79	5	SN	Roadside
	11/18/79	7	SN	Roadside
Peckhamia picata (Hentz)	10/12/78	2	SN	Roadside
Salticus scenicus (Linnaeus)	7/25/79	7	P	Building
Sitticus palustris (Peckham)	5/27/78	8	P	Forest
	10/15/78	1	SN	Roadside
Sitticus floridanus Gertsch & Mulaik	4/11/79	4	SN	Roadside
Naevia vittata (Hentz)	6/18/79	7	SN	Roadside
	11/7/79	8	SN	Roadside
Hentzia mitrata (Hentz)	7/25/79	7	SN	Roadside
Hentzia palmarum (Hentz)	4/11/79	4	P	Forest
Aglenidae				
Agelenopsis naevia (Walckenaer)	10/12/78	2	P	Roadside
	12/4/78	3	P	Roadside
	4/11/79	4	P	Roadside
Aglenopsis pennsylvanica (Koch)	10/25/79	5	P	Roadside
	11/18/79	7	P	Roadside
Coras medicinalis (Hentz)	10/18/79	5	P	Roadside
Pisauridae				
Pelopatis undulata Keyserling	6/30/78	6	SN	Roadside
Dolomedes sexpunctatus Hentz	5/27/78	8	P	Pond
	7/25/79	2	P	Pond
Dolomedes scriptus (Hentz)	10/15/78	1	P	Building
	10/18/79	5	P	Roadside
Dolomedes tenebrosus Hentz	7/14/78	1	P	Roadside
Pisaurina mira (Walckenaer)	10/25/79	5	P	Forest
	11/18/79	7	P	Roadside
Tinus peregrinus (Bishop)	7/25/79	4	SN	Roadside
Lycosidae				
Lycosa baltimoriana (Keyserling)	11/7/79	8	P	Forest
Lycosa rabida Walckenaer	6/30/78	6	SN	Roadside
	7/25/79	4	P	Roadside
Lycosa antelucana Montgomery	10/12/78	2	SN	Roadside
Lycosa avida Walckenaer	7/14/78	1	P	Roadside
	10/12/78	2	P	Roadside
	12/4/78	3	SN	Roadside
	6/18/79	7	P	Forest
Lycosa aspersa Hentz	4/13/78	3	P	Roadside
	6/30/78	6	SN	Roadside
Lycosa helluo Walckenaer	7/14/78	1	P	Roadside
	4/11/79	4	P	Forest

General Notes

Lycosidae				
Lycosa punctulata Hentz	7/25/79	4	P	Roadside
	10/18/79	5	P	Roadside
Lycosa gulosa Walckenaer	10/12/78	1	P	Forest
	11/18/79	7	P	Forest
Lycosa frondicola Emerton	5/27/78	8	P	Forest
Lycosa carolinensis Walckenaer	7/15/79	2	P	Roadside
	7/25/79	4	P	Roadside
Lycosa pratensis (Emerton)	10/18/79	5	SN	Roadside
Pardosa distincta (Blackwall)	10/15/78	1	SN	Roadside
	7/15/79	2	P	Forest
Pardosa milvina (Hentz)	12/10/78	2	P	Forest
Pardosa pauxilla Montgomery	7/25/79	7	SN	Roadside
Pardosa saxatillis (Hentz)	6/30/78	6	SN	Roadside
Trochosa pratensis (Emerton)	7/25/79	4	P	Roadside
	10/18/79	5	SN	Roadside
Pirata sedentarius Montgomery	6/18/79	7	SN	Roadside
Pirata insularis Emerton	4/11/79	4	P	Roadside
Pirata minutus Emerton	11/7/79	8	SN	Roadside
Pirata sylvanus Chambers & Ivie	10/15/78	1	SN	Roadside
Arctosa littoralis (Hentz)	12/4/78	3	SN	Roadside
Arctosa funerea (Hentz)	5/27/78	8	P	Forest
Oxyopidae				
Peucetia viridans (Walckenaer)	7/14/78	1	P	Roadside
	12/4/78	3	P	Roadside
	4/11/79	4	SN	Roadside
	6/18/79	7	P	Roadside
Oxyopes salticus Hentz	5/27/78	8	SN	Roadside
	11/7/79	8	MD	Building
	10/18/79	5	P	Forest
Hamataliwa helia Brady	7/15/79	2	SN	Roadside
Theridiidae				
Theridion tepidariorum (Koch)	7/14/78	1	P	Building
	10/15/78	1	P	Building
	12/10/78	2	P	Building
	7/15/79	2	P	Building
	10/12/78	2	P	Building
	12/4/78	3	P	Building
	4/13/78	3	P	Building
	4/11/79	4	P	Building
	7/25/79	4	P	Building
	10/25/79	5	P	Building
	10/18/79	5	MD	Building
	6/30/78	6	P	Building
	11/18/79	7	P	Building
	11/7/79	8	P	Building
Theridion flavonotatum Keyserling	4/13/78	3	SN	Roadside
Theridion frondeum Hentz	7/25/79	7	MD	Building
	10/18/79	5	SN	Roadside
Theridion differens Emerton	5/27/78	8	SN	Roadside
Spintharus flavidus Hentz	7/25/79	4	SN	Roadside
	10/18/79	5	P	Roadside
Teutana triangulosa (Walckenaer)	7/14/78	1	P	Building
	4/11/79	4	P	Building
	6/18/79	7	SN	Roadside
Ctenium riparius (Keyserling)	10/25/79	5	SN	Roadside
Ulesanis americana Emerton	6/30/78	6	P	Building
	7/14/78	1	P	Building
	11/7/79	8	P	Building
Theridula emertoni (Walckenaer)	5/27/78	8	SN	Roadside
Latrodectus mactans (Fabricius)	10/12/78	1	P	Building
	12/4/78	3	P	Roadside
	7/25/79	7	P	Roadside
	12/10/78	2	P	Building
	11/7/79	8	P	Building
	6/18/79	7	P	Roadside
Euryopis limbata (Walckenaer)	12/4/78	3	SN	Roadside
Conopistha trigona (Hentz)	6/30/78	6	P	Building
	6/18/79	7	P	Building
Argyrodes nephilae Taczanowski	4/11/79	4	P	Building
Araneidae				
Micrathena mitrata (Walckenaer)	9/16/78	4	SN	Roadside
Micrathena gracilis (Walckenaer)	8/10/78	1	SN	Forest
	12/3/79	8	SN	Roadside
	7/15/78	3	P	Forest
Micrathena sagittata (Walckenaer)	8/10/78	1	P	Forest
	12/3/79	8	P	Forest
	7/15/78	3	P	Forest
	7/15/79	7	P	Forest
	9/16/78	4	P	Forest
Verrucosa arenata (Walckenaer)	5/7/78	1	P	Forest
	7/15/79	9	P	Forest
Neoscona benjamina (Walckenaer)	10/11/79	6	P	Forest
Neoscona pratensis (Hentz)	6/12/79	6	P	Forest
Neoscona domiciliorum (Hentz)	7/15/79	6	P	Forest
Neoscona arabesca (Walckenaer)	9/11/78	5	MD	Building
	8/24/79	8	MD	Building
	10/25/79	5	P	Forest
Neoscona sacra (Walckenaer)	10/11/79	6	P	Forest
Mangora gibberosa (Hentz)	11/18/79	7	P	Forest
	6/18/79	7	MD	Building
Araneidae				
Mangora placida (Hentz)	9/16/78	4	P	Forest
	10/11/79	6	P	Forest
Cyclosa conica (Pallas)	9/11/78	5	MD	Building
	6/12/79	6	P	Building
Argiope aurantia Lucas	4/11/79	4	P	Building
	6/18/79	7	P	Forest
	8/24/79	8	P	Building
	5/7/78	1	P	Forest
Argiope trifasciata (Forskal)	7/14/78	1	P	Forest
	4/11/79	4	P	Roadside
	6/18/79	7	P	Forest
Theridiosoma gemmosa (Koch)	7/15/79	6	P	Forest
Araneus cavatica (Linnaeus)	5/7/78	1	P	Roadside
	7/15/78	3	P	Roadside
	9/11/78	5	P	Forest
	7/15/79	7	P	Roadside
Araneus thaddeus (Linnaeus)	12/4/78	3	SN	Roadside
Araneus frondosa (Linnaeus)	6/30/78	6	SN	Roadside
Araneus nordmanni (Thorell)	10/12/78	2	SN	Forest
Araneus marmoreus (Clerck)	10/12/78	1	P	Roadside
	10/25/79	7	P	Roadside
	11/18/79	5	P	Forest
	9/16/78	4	P	Roadside
	10/11/79	6	P	Forest
Drexilia directa (Hentz)	4/11/79	4	P	Forest
	11/18/79	5	SN	Roadside
Eustala anastera (Walckenaer)	6/12/79	7	P	Forest
	10/11/79	6	P	Forest
Gasteracantha elipsoides (Walckenaer)	7/15/78	3	P	Forest
	9/11/78	5	P	Forest
	8/24/79	8	P	Forest
	11/18/79	7	P	Forest
Acanthepeira stellata (Walckenaer)	7/15/78	3	P	Forest
	12/4/78	3	P	Forest
	6/30/78	6	P	Forest
	7/25/79	4	P	Forest
Acanthepeira morsta Comstock	10/25/79	5	P	Forest
Acacesia hamata (Hentz)	4/11/79	4	MD	Building
	8/24/79	8	SN	Roadside
Araniella displicata Chamberlin & Ivie	12/4/78	3	P	Forest
Cyclosa bifurca (Hentz)	4/11/79	4	P	Building
	7/15/79	7	P	Building
Cyclosa conica (Pallas)	10/12/78	1	P	Building
	10/11/79	6	MD	Building
	8/24/79	8	MD	Building
Wixtophora bisaccatum Emerton	12/3/79	8	SN	Roadside
Conopeira ozarkensis Archer	10/12/78	2	SN	Roadside
Epeira cornuta (Clerck)	5/7/78	1	SN	Roadside
Nephila clavipes (Linnaeus)	11/7/79	8	P	Forest
Neosconella pegnia (Walckenaer)	10/25/79	5	P	Forest
Singa pratensis Emerton	7/15/78	3	SN	Roadside
	6/12/79	6	SN	Forest
Wixia ectypa (Walckenaer)	10/12/78	2	SN	Forest
	7/15/79	7	SN	Roadside
Tetragnathidae				
Tetragnatha straminea Emerton	9/16/78	4	P	Pond
	7/15/79	7	P	Pond
Tetragnatha laboriosa Hentz	9/16/78	4	P	Pond
	11/7/79	8	P	Pond
Tetragnatha elongata Walckenaer	5/7/78	1	P	Pond
	7/15/78	3	P	Pond
	9/11/78	5	P	Pond
	6/12/79	6	P	Pond
	7/15/79	7	P	Pond
	8/24/79	8	P	Pond
Tetragnatha versicolor Walckenaer	6/30/78	6	P	Pond
	7/25/79	4	P	Pond
Leucauge venusta (Walckenaer)	9/16/78	4	SN	Forest
	8/24/79	8	SN	Roadside
	12/3/79	8	P	Roadside
	10/11/79	6	SN	Forest
Pachygnatha tristriata C. L. Koch	9/16/78	4	SN	Roadside
Mimognatha foxi (McCook)	7/14/78	1	SN	Roadside
Linyphiidae				
Linyphia marginata (Koch)	5/7/78	1	P	Roadside
	7/14/78	1	P	Roadside
	10/12/78	2	P	Roadside
	12/4/78	3	P	Roadside
	4/11/79	4	SN	Roadside
	7/15/79	7	P	Roadside
	8/24/79	8	P	Roadside
	11/7/79	8	SN	Roadside
Linyphia coccinea (Hentz)	9/11/78	5	SN	Roadside
	10/25/79	5	SN	Roadside
	4/11/79	4	SN	Roadside

Frontinella pyramitella (Walckenaer)	9/16/78	4	P	Roadside	*Hiletus puritanus* Chamberlin	9/16/78	4	SN	Roadside
	5/7/78	1	SN	Roadside		6/12/79	6	SN	Roadside
	7/25/79	4	SN	Roadside	*Ero furcator* (Villers)	8/24/79	8	SN	Roadside
	10/18/79	5	P	Roadside		12/4/78	3	SN	Roadside
	11/18/79	7	P	Roadside	Micryphantidae				
Meioneta micaria Emerton	10/25/79	5	SN	Roadside	*Eperigone tridentata* (Emerton)	7/15/79	7	S	Forest
Meioneta fabra (Keyserling)	7/15/79	2	SN	Roadside	*Eperigone maculata* (Banks)	612/79	6	S	Forest
Mimetidae					*Eperigone autumnalis* (Emerton)	10/15/78	1	S	Forest
Mimetus interfector Hentz	5/7/78	1	SN	Roadside	*Grammonata maculata* (Banks)	11/18/79	7	S	Forest
					Grammonata inonta (Emerton)	4/11/79	4	S	Forest
						10/25/79	5	S	Forest
					Walckenaera vigilax (Blackwall)	7/15/79	2	S	Forest

* Species not published prior to the present collection.

** 1 Donaldson, 2 Randall, 3 Columbus, 4 Fordyce, 5 Fulton, 6 White Oak Lake, 7 Garland City, 8 El Dorado

*** S—Sieve, SN—Sweep net, P—Hand picking, MD—Mud-dauber nests

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PROFILE OF HUMAN-RABID SKUNK CONTACTS IN ARKANSAS: 1977-1979

In recent years, rabies has become a serious problem in the striped skunk *(Mephitis mephitis)* population of Arkansas. With 98 positive cases in 1977, 140 in 1978 and 297 in 1979, Arkansas ranks first in the number of skunk rabies per square mile. The Arkansas Department of Health, in 1979, declared rabies in striped skunks to be of epidemic proportion. This paper presents a profile of human contacts with rabid skunks over this three-year period.

Using information gathered from the Arkansas Department of Health, those individuals who had contact with laboratory-confirmed rabid skunks were interviewed either by questionnaire or by telephone in an effort to determine the behavior of the skunk, the habitat in which the skunk was killed, time of day of the contact and whether or not other skunks had been seen behaving in a similar manner. Response to this poll varied from 40% in 1977, 80% in 1978 and 95% in 1979.

Table 1 summarizes the behavior of rabid skunks at the time contact was made. As can be seen, roughly half of the skunks behaved in an aggressive manner. Another one-third were either non-aggressive but unafraid or behaved in a sick or disoriented manner. These data agree with Richards' (1957. North Dakota Outdoors 20:4-5, 16) observations that rabid skunks are "most aggressive and determined" than any other form of wildlife in their attacks on humans and on other animals. Table 2 indicates that most rabid skunks in the acute state of infection are solitary.

Table 3 identifies habitats in which the skunks were killed. Over half of the skunks were killed in and around buildings in the country. The striped skunk is increasingly being found in close approximation to human habitation (Verts. 1967. The biology of the striped skunk. Univ. Ill. Press. 218 pp.). The fact that such a large number of the rabid skunks were killed in and around buildings, further demonstrates the potential danger of rabies to human and domestic animals.

Most of the rabid skunks encountered in these three years (75%) were active during daylight hours (Table 4). To some degree, this may reflect human activity patterns. However, it clearly illustrates that the rabid skunk's activity often deviates drastically from the normal nocturnal or crepuscular pattern.

Table 1. General Behavior of Rabid Skunk

BEHAVIOR	1977	1978	1979	TOTAL
Aggressive	12(37)[1]	63(60)	122(46)	197(48)
Unafraid but not aggressive	6(18)	14(13)	54(20)	74(18)
Disoriented or sick	11(33)	15(14)	62(23)	88(22)
Normal	1(3)	4(4)	6(2)	11(3)
Dead	3(9)	10(9)	25(9)	38(9)

1 - Parenthesis indicates percentage

Table 2. Have Other Skunks Been Seen Behaving in a Similar Manner?

	1977	1978	1979	TOTAL
YES	9(29)[1]	28(27)	69(26)	106(26)
NO	22(71)	76(73)	199(74)	297(74)

1 - Parenthesis indicate percentage

Table 3. Habitat Skunk Killed

HABITAT	1977	1978	1979	TOTAL
Woodland	3(8)[1]	20(14)	51(13)	74(13)
Open Field or Pasture	3(8)	20(14)	68(17)	91(16)
Buildings in Country	17(71)	88(61)	199(51)	314(55)
Inside City Limits	4(10)	10(7)	29(8)	43(8)
Along Railroad	0(0)	0(0)	15(4)	15(3)
Edge of Water Source	1(3)	5(4)	25(7)	31(5)

1 - Parenthesis indicate percentage

Table 4. Time of Day Skunk Killed

TIME	1977	1978	1979	TOTAL
6:00-12:00 A.M.	19(58)[1]	44(42)	131(48)	194(47)
12:00-6:00 P.M.	6(18)	29(28)	81(29)	116(28)
6:00-12:00 P.M.	5(15)	15(15)	35(13)	55(14)
12:00-6:00 A.M.	3(9)	15(15)	28(10)	46(11)

1 - Parenthesis indicate percentage

While these data are based on observations made by untrained persons, we feel that they are consistent enough to draw the following profile: the rabid skunk coming in contact with humans generally will be solitary, aggressive or unafraid and found around buildings in the country during the daylight hours (usually in the morning). Since over 85% of skunks tested by the Arkansas Department of Health are positive for rabies, 90% of the total cases of rabies are attributable to skunks and because of the epidemic of skunk rabies, any skunk seen during daylight hours in Arkansas should be assumed rabid and treated accordingly. Also, Parker (1962. Proc. U.S. Livestock Sanit. Assoc. 65:273-280) stated that in areas where rabies in skunks is prevalent, sighting a skunk during daylight hours is "reasonable grounds to suspect the animal of being infected with the disease." The characteristics outlined herein demonstrate the effectiveness of the skunk as a perpetuator and disseminator of rabies.

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SIGNIFICANT ADDITIONS TO THE MOLLUSCAN FAUNA OF THE ILLINOIS RIVER, ARKANSAS

In Gordon et al. (1980a), the molluscan fauna of the Illinois River in northwestern Arkansas was described. Thirty-nine taxa were listed. This faunal assemblage was compared to Branson (1967), the only other available report on the molluscan fauna of an Ozarkian west slope drainage, and some aspects of the local distribution of species endemic to the Interior Highlands were discussed. The distribution and identification of endemic forms and the Arkansas unionacean fauna have been further discussed in Gordon et al. (1980b). During the past year, additional samples were collected from the Illinois River and west slope drainages in Missouri (tributaries of the Neosho River). Methods were previously described (Gordon et al. 1980a).

Fusconaia ozarkensis (Call) and *Pisidium fallax* Sterki have been identified from the Illinois River. Additionally, *F. ozarkensis* is reported for the first time from Kansas (Spring River), and the Kansan records of Call (1885-1887) and Scammon (1906) are confirmed for *Actinonaias ellipsiformis ellipsiformis* (Conrad) (see Murray and Leonard, 1962) which appears to have been recently misinterpreted as *Villosa iris* (Lea) by Schuster and DuBois (1979). Within the larger drainage systems of the west slope of the Ozark Plateaus, the unionid fauna appears to be fairly similar (Table 1).

The Interior Highlands are composed of two separate geological assemblages which have been shown to possess a distinct endemic molluscan fauna (van der Schalie and van der Schalie, 1950; Gordon et al. 1980b). Of the eight endemic taxa of Unionidae, six are known to occur in the Ozark Plateaus, four of these six are restricted to the Ozark Plateaus, and the other two are distributed throughout the region (*Ptychobranchus occidentalis* [Conrad] and *Cyprogenia aberti* [Conrad]). The remaining two species, *Arkansia wheeleri* Ortmann and Walker and *Villosa arkansasensis* (Lea), are restricted to the Ouachita Mountains (Gordon et al. 1980b). Collections from the areas adjacent to the Illinois River have shown *Lampsilis reeveiana* (Lea) and *Actinonaias ellipsiformis pleasii* (Marsh) to be present in the southern Ozarkian drainage of the White River but not the west slope drainages represented by the Illinois, Elk, and Spring rivers. Likewise, *L. rafinesqueana* Frierson occurs throughout the west slope drainages (Table 1) but not in the White River. *Fusconaia ozarkensis* is common to both the south and the west slope drainage systems.

Three natural unionacean faunal subdivisions appear to be present in the Ozark Plateaus. The west slope fauna is typified by *F. ozarkensis* and *L. rafinesqueana*. The fauna south of the Ozark Crest is composed of *F. ozarkensis, A. ellipsiformis pleasii,* and *L. reeveiana*. North of the Ozark Crest, the only endemic unionid is *L. reeveiana*. The overlap within these subdivisions and the presence of the two wide-spread species illustrates the close affinity of the fauna.

Further observations of the unionid fauna suggest some additional associations. *Cyprogenia aberti* is generally distributed throughout the Interior Highlands and west into Oklahoma and Kansas (Gordon et al. 1980b) and has been found throughout the Spring River system. For these reasons, it is highly probable that *C. aberti* is present in the Illinois River, although it may occur only downstream in Oklahoma. Similar distribution patterns are reflected in the occurrence of several other species listed by Branson (1967) for the lower Spring River (see Table 1). Also, *Alasmidonta marginata* Say and *A. calceola* (Lea) have been recorded from the Elk and Spring rivers (Table 1). They are known historically from the White River (Gordon et al. 1980b). Baker (1928) has noted a close distributional association between these two species of *Alasmidonta*. The small size and habit of burrowing into the substrate by *A. calceola* make it difficult to find (Utterback, 1915; Baker, 1928). *Alasmidonta marginata* was found in the Illinois River; therefore, it is postulated that *A. calceola* also occurs in the Illinois River.

Pisidium fallax generally has been considered a northern species. With exception of a single record from Alabama, it had not been found south of the extent of maximum glaciation. Its presence in the Illinois River and several adjacent drainages represents a new regional record for this species (Gordon et al. 1980c). These records and Wheeler's (1918) observations on the Ouachita Mountains molluscan assemblage illustrate the need for further study of the Sphaeriidae within the Interior Highlands. *Pisidium fallax* easily may be mistaken for *P. casertanum* or *P. compressum*. Its designation as the "deceptive" (from the Latin, *fallac*) *Pisidium* appears to have been appropriate.

Table 1. Species of Unionidae from three drainage systems of the Ozark Plateaus west slope (compiled from Oesch, *pers. comm.*; Buchanan, *pers. comm.*; Gordon et al. 1980a; and authors' personal collections).[1]

SPECIES	ILLINOIS	ELK	SPRING
Fusconaia flava	X	X	X
Fusconaia ozarkensis	X	X	X
Megalonaias gigantea[2]	X		
Amblema plicata	X		X
Quadrula pustulosa	X	X	X
Quadrula quadrula[3]	X		X
Quadrula metanevra			X
Quadrula cylindrica	X		X
Tritogonia verrucosa	X		X
Cyclonaias tuberculata		X	
Pleurobema cordatum	X	X	X
Elliptio dilatatus	X		X
Lasmigona costata	X	X	X
Alasmidonta calceola		X	X
Alasmidonta marginata	X	X	X
Anodonta grandis	X	X	X
Anodonta imbecilis	X	X	X
Strophitus undulatus	X	X	X
Ptychobranchus occidentalis	X		X
Cyprogenia aberti			X
Actinonaias carinata	X	X	X
Actinonaias ellipsiformis ellipsiformis	X	X	X
Leptodea fragilis		X	
Proptera purpurata	X		
Carunculina parva	X	X	X
Carunculina glans	X	X	X
Villosa lienosa	X		
Ligumia subrostrata	X	X	X
Lampsilis radiata siliquoidea	X		X
Lampsilis rafinesqueana	X	X	X
Lampsilis ovata	X	X	X

[1]Branson (1967) has not been included here due to sample locations in the lower Spring River. Similar locations have not yet been sampled in the Illinois River or are inundated by Grand Lake O' the Cherokees in the Elk River.
[2]This species appears to have been introduced into an impoundment on a small tributary of the Illinois River.

We would like to express our appreciation to Mr. Alan C. Buchanan of the Missouri Department of Conservation, Columbia, Missouri, and Mr. D. Ronald Oesch, Glendale, Missouri, for information concerning their collections from the Ozark west slope. The Kansas records for *Fusconaia ozarkensis* and *Actinonaias ellipsiformis ellipsiformis* were identified from a collection (Spring River) made by Mr. Charles Cope, Department of Biological Sciences, Wichita State University, Wichita, Kansas.

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General Notes

HETEROCHROMATIC PATTERNS IN *DROSOPHILA VIRILIS* INTERPHASE NUCLEI

In interphase nuclei of *Drosophila* there is a distinct chromocenter. This is clearly seen in salivary gland preparations where one large chromocenter is present with all of the chromosomes attached to it. In the large nuclei of the larval brain a distinct chromocenter can be demonstrated when these cells are treated to show chromosomal heterochromatin.

HSU (1971) and Beck (1977) demonstrated that the regions near the centromere in *Drosophila melanogaster* and *D. virilis* were heterochromatic and comparable to the constitutive heterochromatin composed of satellite DNA of mammalian chromosomes. Gall et al. (1973) found three satellite DNAs in *D. virilis* that were rich in adenine and thymine. Ellison and Barr (1972) and Mayfield and Ellison (1975) showed that there were two to three A-T rich satellites localized in interphase nuclei as heterochromatic masses when studied with fluorescence staining. This study was made to see if the chromocenters observed in interphase nuclei correspond to the heterochromatic masses demonstrated with fluorescence stains.

Slides of larval ganglia of *D. virilis* were prepared according to Guest (1975) and the giant interphase nuclei were treated to demonstrate heterochromatin following Hsu (1971). These giant cells were counted in a mixture of cells from male and female larvae. Of 100 nuclei counted, 86 showed a single heterochromatic mass, 11 had two chromocenters, and three showed three chromocenters. Since the Y chromosome is completely heterochromatic, 25 cells from male larvae were studied to determine if the appearance of two or more chromocenters was related to the sex chromosomes. Of the 25 nuclei counted, 23 had one chromocenter (92%), and two had two heterochromatin masses (8%). This is comparable to the 86% of the mixed population that showed a single chromocenter. Thus, it appears that the presence of two chromocenters is not related to the sex chromosomes.

In examining cells with a single chromocenter, 12 showed an irregular mass with one or two extensions from the mass. This also was apparent in four of the 11 nuclei studied that had two chromocenters.

Mayfield and Ellison (1975) suggested a one to one correspondence between the number of heterochromatic masses and satellite DNA and showed with fluorescence techniques that the single heterochromatic mass could be distinguished as three A-T rich satellites. The Giemsa technique will not discriminate between DNA satellites. However, the fact that 14% of the nuclei showed two or more chromocenters indicates that in some cases the constitutive heterochromatin composed of satellite DNA does separate and can be distinguished by Giemsa staining. The irregular shape of many of the chromocenters may also be an expression of the partial separation of the satellite DNAs. Ellison and Barr (1972) suggested that the number of chromocenters present could result from chromosome orientation in anaphase. Heterochromatin in close proximity would form the chromocenter, and this association would persist throughout the following interphase. Each of the six pairs of chromosomes in *D. virilis* contains the same satellite DNAs and if, in anaphase, these fuse, the resulting chromocenter would be observed in interphase until the S phase when the satellite DNA begins replication.

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AQUATIC MACROINVERTEBRATES OF WAPANOCCA NATIONAL WILDLIFE REFUGE

Wapanocca Lake and its contiguous swamps may have been formed by the New Madrid earthquakes of 1811-12, but probably predate this event. The area had flourishing willow and cypress stands prior to 1827 (Madden, M. R. 1978. Wapanocca: A History - Hunting Club to Wildlife Refuge. Appendix II. *In:* Jackson, H. E. 1979. A Cultural Resources Reconnaisance of Wapanocca National Wildlife Refuge. Vol. II. Report prepared by the Research Institute, NE Louisiana Univ. 120 p.). However, infrequent and moderate habitat alteration has occurred since that time. Wapanocca Lake was drained in 1968, and a levee system was constructed to inhibit inflow of silty and potentially contaminated waters from surrounding intensively cultivated farmland and from the Mississippi River. General repair work and undergrowth removal were also undertaken at this time. The lake was again drained in 1979 and repairs were made. On both occasions the lake was refilled with relatively silt-free deep-well water.

The refuge, located approximately 6.5 km W of the Mississippi River and 0.4 km S of Turrell, Crittenden County, Arkansas, consists of 2,220 ha, fairly equally proportioned among three major habitat types. These are the freshwater impoundment, which includes the 240 ha Wapanocca Lake and cypress-willow swamp; bottomland timber, which is seasonally flooded; and agricultural land, which is cooperatively farmed, with the refuge receiving suplemental waterfowl foods (Fig. 1). Primary functions of this refuge are to provide a wintering area for migratory waterfowl, to provide a nesting and brooding area for resident wood ducks, and to serve as a link in the chain of refuges along the Mississippi River to encourage the southward migration of Canada Geese. Secondary functions are to maintain representative populations of indigenous species associated with bottomland hardwood forests, and to provide for the public enjoyment of all migratory bird resources (Wapanocca National Wildlife Refuge records).

The purpose of this study was to ascertain the success of this refuge in attaining one of its goals, specifically the maintenance of indigenous species populations. Further, this study contributes to our knowledge of the native fauna of Arkansas.

Eight trips and 14 discrete collections were made between 8 March 1977 and 8 March 1980 (Table 1, Fig. 1). On most occasions, aquatic dip nets were used, and specimens were preserved in 70% EtOH. Adult odonates were collected with sweep nets, papered, placed in acetone overnight, then placed in clear plastic envelopes with data cards. A light trap was used on 1 October 1979, and all adult caddisfly and true fly data are from this collection. All specimens are catalogued and housed in the ASU aquatic macroinvertebrate collection.

One hundred sixty-three taxa were collected, of which 130 were identified to species or subspecies (Table 2). Greatest diversity was provided by Coleoptera (39 taxa), Diptera (31 taxa) and Hemiptera (21 taxa). The composition of the aquatic macroinvertebrate community reflects the refuge's shallow, thickly vegetated nature. Coleoptera and Hemiptera are, in general, poorly adapted to an aquatic existence, and do best in such habitats. The Diptera collected are characteristic of aquatic ecosystems having a rich organic substrate.

Six species known to be new state records are designated by an asterisk (Table 2). Five of these *(Ranatra australis, R. buenoi, Potamyia flava, Oxyethyra pallida* and *Oecetis distissa)* are common, widespread, and their occurrence has been published for most contiguous states. The publication of such common species as new state records for Arkansas emphasizes our lack of knowledge regarding many Arkansas floral and faunal groups.

The sixth species, *Caecidotea laticaudata*, shows some differences from the original description (Williams, W. D. 1970. A revision of North American epigean species of *Asellus* (Crustacea: Isopoda). Smithsonian Contr. to Zool. 49:1-80), and approaches *C. foxi* (Flemming, L. E. 1972. The evolution of the eastern North American isopods of the genus *Asellus* (Crustacea: Asellidae). Part I. Int. J. Speleol. 4:221-256) in some respects, especially in the long cannula on the second pleopod endopod of the male. Either *C. laticaudata* is a variable species that includes *C. foxi* and the Wapanocca specimens, or the Wapanocca specimens represent an undescribed species (Thomas E. Bowman, Crustacea Curator, Natl. Museum of Natural History, *pers. comm.*).

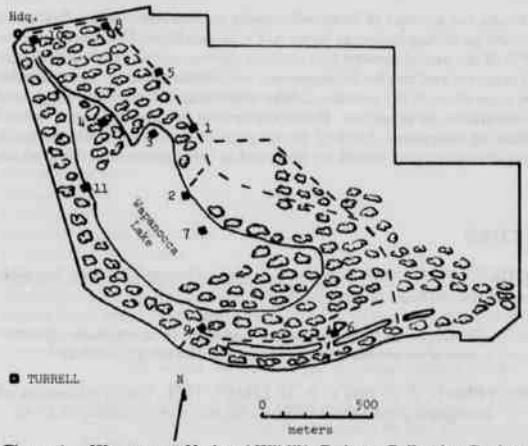

Figure 1. Wapanocca National Wildlife Refuge. Collecting Stations are designated by numbers 1-11.

Table 1. Collecting Stations and Dates, Wapanocca National Wildlife Refuge.

Station*	Description of Station with date
1	Borrow pit 600 m N of observation tower. 3 March 1977.
2	Observation tower. 3 March 1977, 28 July 1978, 1 October 1979.
3	North corner of Wapanocca Lake. 5 May 1977.
4	Boat trail. 5 May 1977.
5	Borrow pit 1500 m NNW of observation tower. 11 August 1977.
6	NW corner of Woody Pond 2. 11 August 1977.
7	Water lotus bed, Wapanocca Lake. 29 October 1977.
8	Borrow pit 1200 m E of headquarters building. 29 October 1977.
9	NW corner of Woody Pond 1. 28 July 1978.
10	Boat landing 100 m SE of headquarters building. 21 April 1979, 8 March 1980.
11	Public boat launching area. 8 March 1980.

*Station numbers correspond with those of Figure 1.

The diversity of aquatic macroinvertebrates in this refuge suggests three things. First, a variety of microhabitats is available. The borrow pits immediately adjacent and parallel to the levees consistently yielded the greatest diversity of macroinvertebrates. Swamp habitat also supported a diverse fauna. Diversity of aquatic plants was greatest in these areas, and water depth varied to a maximum of 2 m. Cypress stands supported fewer species, because fewer microhabitats are present in these nearly homogeneous stands. A second point regards food. The abundant decomposing vegetation in fairly shallow, fairly clear water allows rapid recycling of nutrients. This contributes greatly to the food base and supports a numerically dense macroinvertebrate community as well as a diverse one. Finally, the diversity and abundance of aquatic macroinvertebrates suggest that this refuge possesses water of good quality. Neither turbidity nor potential contaminants become limiting, it would appear. The diversity and density of molluscs also suggest that the water is at least moderately hard and therefore has some buffering capacity. Little information has been published concerning the water quality requirements of aquatic Hemiptera. Nevertheless, personal observations indicate that certain taxa (e.g. *Merragata, Pelocoris, Neoplea*) require undisturbed, clean habitat for population development. *Neoplea striola* requires static, shallow, clear water where there is an organic bottom and a high nutrient source with thin-stemmed or narrow-leaved vegetation (Gittleman, S. H. 1974. The habitat preference and immature stages of *Neoplea striola* (Hemiptera: Pleidae). J. Kansas Entomol. Soc. 47(4):491-503). In the present study *Peloccoris* was taken regularly, and one series of 73 specimens was collected in a short period of time. *Neoplea* was collected on every occasion, and once was captured at an estimated rate of 100 individuals per dip net sample.

We conclude that Wapanocca National Wildlife Refuge is successfully maintaining populations of species indigenous to Arkansas' bottomland hardwood forests. Such sanctuaries are an important counterbalance to man's continued alteration of his environment.

We thank Bill A. Grabill, former Refuge Manager, Joseph A. Oliveros, current Acting Refuge Manager, and their personnel for their considerable assistance in conducting this study. The following persons identified and/or confirmed identifications of the indicated taxa: Donald Newton (Turbellaria, *Aelosoma, Stylaria*), Jarl K. Hiltunen (Oligochaeta), Donald J. Klemm (Hirudinea), Mark Gordon (Mollusca), Thomas E. Bowman (Isopoda), H. H. Hobbs, Jr. *(Procambarus)*, Paul Kittle (Gerridae), John T. Polhemus (selected Hemiptera), Guenter A. Schuster (Trichoptera), H. H. Neunzig *(Ostrinia)*, Paul J. Spangler (selected Dytiscidae, Helodidae, Noteridae), Frank N. Young (selected Hydrophilidae), Warren U. Brigham *(Peltodytes)*, W. W. Wirth (*Atrichopogon*, Chironomidae, Stratiomyidae), W. M. Beck, Jr. (Chironomidae), F. C. Thompson *(Chrysops)*, and W. N. Mathis (Tipulidae).

Table 2. Aquatic Macroinvertebrates of Wapanocca National Wildlife Refuge.

TURBELLARIA
Macrostomum appendiculatum? (Fabricius)
Macrostomum tubum (Graff)
Catenula
Microdalyellia
Gyratrix hermaphroditus Ehrenberg
Mesostoma ehrenbergii (Focke)
Mesostoma lingua? Schmidt
Mesostoma vernale? Hyman
Phaenocora highlandense Gilbert
Phaenocora lutheri? Gilbert
Rhynchomesostoma rostrata (Muller)
Typhloplana viridata (Abildgaard)
OLIGOCHAETA
Aelosoma
Dero digitata (Muller)
Haemonais waldvogeli Bretscher
Stylaria fossularis Leidy
Aulodrilus pigueti Kowalewski
Limnodrilus hoffmeisteri Claparede
Peloscolex multisetosus (Smith)
HIRUDINEA
Erpobdella punctata (Leidy)
Mooreobdella microstoma (Moore)
Helobdella stagnalis (Linnaeus)
Helobdella triserialis (Blanchard)
Placobdella montifera Moore
Placobdella ornata (Verrill)
GASTROPODA
Goniobasis potosiensis plebeius (Anthony)
Viviparus intertextus (Say)
Lymnaea (Pseudosuccinea) columella (Say)
Gyraulus parvus (Say)
Helisoma trivolvis (Say)
Menetus dilatatus (Gould)
Physa gyrina? Say
PELECYPODA
Musculium lacustre (Muller)
Musculium transversum (Say)
Carunculina parva (Barnes)
ISOPODA
**Caecidotea laticaudata?* (Williams)
Caecidotea obtusa (Williams)
Lirceus
AMPHIPODA
Hyalella azteca (Sassure)
Crangonyx sp. nr. *gracilis* Smith
DECAPODA
Palaemonetes kadiakensis Rathbun
Procambarus (Ortmannicus) acutus acutus (Girard)
COLLEMBOLA
Isotomurus palustris (Muller)
Podura aquatica Linnaeus
Sminthurides
HEMIPTERA
Belostoma lutarium (Stal)
Hesperocorixa lucida (Abbott)
Hesperoxorixa nitida (Fieber)
Trichocorixa calva (Say)
Trichocorixa kanza Sailer
Gelastocoris oculatus (Fabricius)
Gerris marginatus Say
Limnoporus canaliculatus (Say)
Merragata brunnea Drake
Hydrometra
Mesovelia mulsanti White
Pelocoris femoratus (Palisot de Beauvois)
**Ranatra australis* Hungerford
**Ranatra buenoi* Hungerford
Ranatra nigra Herrick-Shaffer
Notonecta irrorata Uhler
Notonecta raleighi Bueno
Notonecta undulata Kirkaldy
Neoplea striola (Fieber)
Microvelia hinei Drake
Microvelia pulchella Westwood
EPHEMEROPTERA
Caenis
Callibaetis
ODONATA
Argia
Anomalagrion hastatum (Say)
Enallagma civile (Hagen)
Enallagma signatum (Hagen)
Ischnura posita (Hagen)
Gomphus maxwelli Ferguson
Anax junius Drury
Epitheca cynosura (Say)
Erythemis simplicicollis Say
Libellula vibrans Fabricius
Pachydiplax longipennis Burmeister
Pantala flavescens Fabricius
Perithemis tenera Say
Plathemis lydia Drury
Tramea lacerata Hagen
MEGALOPTERA
Chauliodes rastricornis Rambur
TRICHOPTERA
Hydropsyche
**Potamyia flava* (Hagen)
Orthotrichia aegerfasciella (Chambers)
**Oxyethira pallida* (Banks)
Agrypnia vestita (Walker)
Oecetis cinerascens (Hagen)
**Oecetis distissa* Ross
Oecetis inconspicua (Walker)
LEPIDOPTERA
Ostrinia penitalis Grote
COLEOPTERA
Phytobius velatus Beck
Agabus aeruginosus Aube
Bidessonotus inconspicuous (LeConte)
Celina angustata Aube
Coptotomus venustus Say
Hydroporus hybridus (Aube)
Hydroporus rufilabris Sharp
Hydroporus undulatus undulatus Say
Hydrovatus pustulatus compressus Sharp
Hydrovatus pustulatus pustulatus Melsh.
Laccophilus fasciatus rufus Melsh.
Laccophilus maculosus maculosus Say
Laccophilus proximus proximus Say
Matus bicarinatus (Say)
Neobidessus pullus pullus (LeConte)
Thermonectes basillaris (Harris)
Uvarus granarius (Aube)
Uvarus lacustris (Say)
Hydrocanthus iricolor atripennis Say
Suphisellus parsoni Young
Gyrinus analis Say
Peltodytes dunavani Young
Peltodytes sexmaculatus Roberts
Cyphon
Berosus pantherinus LeConte
Cercyon mendax Smetana
Enochrus consortus Green
Enochrus ochraceus (Melsh.)
Helochares maculicollis Mulsant
Helocombus bifidus LeConte
Helophorus
Hydrochus rufipes Melsh.
Hydrochus subcupreus LeConte
Hydrophilus triangularis Say
Paracymus subcupreus (Say)
Tropisternus blatchleyi blatchleyi d'Orch.
Tropisternus lateralis nimbatus (Say)
Tropisternus mexicanus mexicanus LaPorte
Tropisternus mexicanus striolatus (LeConte)
DIPTERA
Atrichopogon
Chaoborus punctipennis (Say)
Ablabesmyia peleensis (Walley)
Ablabesmyia
Clinotanypus pinguis (Loew)
Chironomus crassicaudatus Malloch
Coelotanypus
Cricotopus remus Sublette
Cricotopus
Dicrotendipes nervosus (Staeger)
Einfeldia
Endochironomus nigricans (Johannsen)
Glyptotendipes lobiferus (Say)
Glyptotendipes
Goeldichironomus holoprasinus (Goeldi)
Hydrobaenus
Kiefferulus dux (Johannsen)
Larsia
Lauterborniella
Parachironomus
Polypedilum illinoense (Malloch)
Polypedilum
Procladius
Tanypus
Culex territans Walker
Empididae
Sepedon
Odontomyia
Stratiomys
Chrysops
Tipula

*Denotes new state records

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GROWTH PATTERNS, BEHAVIOR AND FOOD ITEMS FED TO NESTLING GREAT HORNED OWLS (*BUBO VIRGINIANUS*)

Two nestling Great Horned Owls *(Bubo virginianus)* were observed for 47 days from 10 March to 25 April, 1979. The nest was located three miles south of Batesville, Independence County, Arkansas. The habitat surrounding the nest site consisted of an open rocky meadow three to five acres in size. It was bordered by an open and broken oak woods with a mixing of red cedar *(Juniperus virginiana,* Linn.). The nest was in an old fence row lined mainly with red cedar, with the nest situated near the trunk of a red cedar (15 m in height) in branches approximately ten m above the ground. The nest was an abandoned crow's nest constructed of sticks with a diameter of 45 - 60 cm and a depth of six cm.

Observations began when the two nestlings were approximately three days old. Growth and behavior patterns are summarized in Tables 1 and 2. Territory, courtship and nesting of the Great Horned Owl previously have been reported by Miller (1930), Errington (1930, 1932), and Baumgartner (1938, 1939). According to Bent (1938), Great Horned Owls lay their eggs in February and sometimes in January. The incubation period is about 28 days, the young remain in the nest six or seven weeks, and they are unable to fly before they are ten or 12 weeks old. Egg laying for this pair took place around 7 February.

The Great Horned Owl is a ravenous feeder on a variety of animal life and is a generous provider for its young (Bent, 1938). Food items observed in the Batesville nest with the two nestlings included numerous Common Grackles *(Quiscalus quiscula),* one Blue Jay *(Cyanocitta cristata),* one Mockingbird *(Mimus polyglottos),* one Common Flicker *(Colaptes auratus),* two young cottontails *(Sylvilagus floridanus)* and one adult cottontail with hind quarters only and one mole *(Scalopus aquaticus).* All of the passerine birds observed in the nest had their heads removed, apparently being brought to the young owls in this condition. Baumgartner and Baumgartner (1944) summarized food items analyzed from 67 Great Horned Owl pellets in which they recorded 71 food items, collected at Lake Carl Blackwell near Stillwater, Oklahoma. They found the cotton rat *(Sigmodon hispidus)* to be the major food item follows by the cottontail *(Sylvilagus floridanus).* Other food items mentioned in their study included species of shrews, moles, mice and several avian species. Also found were several beetles.

The adult Great Horned Owls apparently abandoned their young or were killed as they did not appear at the nest after 9 April. The nestlings then were removed on the following day and housed in an out-door wire cage. Both nestlings died on 25 April, apparently from the annoyance of large numbers of black flies (Simulidae) which are known to kill turkeys, chickens, pigeons and apparently nestling birds. These flies attack young birds especially around the head region in large numbers.

Table 1. Observations on Growth Patterns of Nestling Great Horned Owls.

Age	
3 days old	All white down feathers. Large beaks, weight 4-6 ounces, eyes barely open.
6 days old	All white down feathers. Little growth, one bird slightly larger than the other.
10 days old	Rapid growth. Brown contour feathers beginning to appear with down feathers.
12 days old	Body weight doubled. Considerable more contour feathers.
14 days old	No change.
16 days old	Contour feathers growing rapidly. Down still present to some extent. Body weight 3 times that when hatched.
20 days old	Contour feathers now cover most of body. Quill feathers developing. Primary coverts showing on wings.
24 days old	Ear tuffs (Horns) now appear.
27 days old	Quill feathers developed on wings. Tail developing rapidly. Weight 12-16 oz.
29 days old	Brown contour feathers developed. Primary coverts and tail feathers developing. Breast bars dark.
36 days old	Eye lashes now appearing. Definite face pattern. Most contour feathers developed.
38 days old	Wing feathers now well developed. Secondary coverts and tail developed.
40 days old	Full feather coloration with wings almost fully developed.
47 days old	Almost ready to fly with body well feathered.

Table 2. Behavioral Patterns of Nestling Great Horned Owls.

Age	Behavior
3-4 days old	Peeping and chirping.
5-6 days old	Chirping loudly. Aware of observer.
9-10 days old	Pair lay close together for support.
10-11 days old	No response to touching.
14 days old	Clapping of beaks first noticed and continuous peeping.
15 days old	Young owls cannot stand by themselves but remain close to each other.
17 days old	Owls standing for first time. Some clapping of beaks.
21 days old	Owls very alert. Movement of head 180 degrees. Owls are able to stand but remain close together. Much clapping of beaks.
24 days old	Smaller of the two owls is less aggressive. The larger one very aggressive and tries to bite.
26 days old	Both birds becomming aggressive. Hissing and both try to bite. If hand fed the aggressiveness stops.
31 days old	Adults have quit feeding young. No adult owls observed in area and no additional food brought to nest.
32 days old	Both very aggressive and hungry.
35 days old	Young remove from nest. Clucking and snapping of beaks.
37 days old	Both are very aggressive in cage.
40 days old	Both attack hand upon feeding. Clapping of beaks when one approaches cage. Hissing and spreading of wings and tail.

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ISOLATION OF PHOSPHOLIPASE A_2 FROM *AGKISTRODON BILINEATUS* VENOM

Venom produced by the Mexican mocassin, *A. bilineatus*, contains phosphomonoesterase, phosphodiesterase, 5'-nucleotidase, esterases, thrombin-like, L-amino acid oxidase, protease, phospholipase A_2, and NAD nucleosidase activities (Tu et al., 1967; Denson et al., 1972; Sifford and Johnson, 1978; Brunson et al., 1978). Of these enzymes, phospholipase A_2 (PhL-A_2) was chosen in this work for possible isolation. This choice of PhL-A_2 for isolation was due primarily to its heat stability and to its distribution in the eluates obtained by ion exchange chromatography of the crude venom as evidenced previously (Sifford and Johnson, 1978).

Assay procedures with minor modifications (Sifford and Johnson, 1978) included phospholipase A_2 using the clearing of an egg yolk suspension (Marinetti, 1965), phosphomonoesterase and phosphodiesterase (Richards et al., 1965), esterase (Tu et al., 1965), 5'-nucleosidase (Lo et al., 1966; Ging, 1956), and L-amino acid oxidase (Paik and Kim, 1965). Hyaluronidase was assayed according to the turbidimetric procedures of Kass and Seastone (1944).

A 450 mg sample of crude venom (Sigma) was separated on Concanavalin A covalently bound to Sepharose 4B gel (Con A) into glycoproteins (anthrone reagent positive) and nonglycoproteins (anthrone reagent negative) by employing the methods of Iscove et al. (1974) and Aspberg and Porath (1970). In fractionations by ion exchange chromatography employing DEAE Sephadex A-50, the methods of Cheng and Ouyang (1967), Ouyang et al. (1971), and Johnson and Sifford (1978) were used. Proteins were desalted by using Sephadex G-10 columns at 4°C. Sephadex G-75 and G-50 columns were used to separate PhL-A_2 from higher molecular weight molecules.

An immunizing schedule was prepared according to Ownby et al. (1979). Preimmune serum was obtained from approximately 12 month old New Zealand white rabbits. An immunizing dose was prepared by dissolving 17 mg of lyophilized *A. bilineatus* crude venom in 20 ml of sterile physiological saline. A 0.5 ml aliquot of this solution was then mixed with 0.5 ml of Freund's complete adjuvant. Injections of 0.5 ml then were made subcutaneously into each thigh. Booster injections were prepared by mixing 0.5 ml of *A. bilineatus* venom (0.8 mg/ml) and 0.5 ml of Freund's complete adjuvant. One week later, subcutaneous injections of 0.5 ml of the solution were made in each shoulder. Four weeks after the booster injections, antiserum via heart puncture was collected and stored at −20°C.

Rabbit antiserum for the purified phospholipase A_2 fraction was prepared by injecting an immunizing dose containing 0.3 ml of purified enzyme (0.1 mg/ml) and 1.0 ml Freund's complete adjuvant. Subcutaneous injections of 0.65 ml of this solution were made into each thigh. One week later, booster injections of the same dose were administered into each shoulder. Four weeks later, antiserum was collected and stored at −20°C.

Immunoelectrophoresis methods outlined by Campbell et al. (1963) and Garvey et al. (1977) were employed to determine PhL-A_2 purity. Dodecyl Sulfate-Polyacrylamide gel electrophoresis procedures of Weber and Osborn (1969) were used by Dr. Collis Geren (University of Arkansas at Fayetteville) to assay crude venom and fraction samples.

A. bilineatus crude venom contains nonglycoprotein and glycoprotein enzymes (Fig. 1). The larger nonglycoprotein fraction (Fraction I), comprising approximately 80% of the crude venom proteins, contained numerous enzyme activities. These included PhL-A_1, phosphomonoesterase, phosphodiesterase, 5'-nucleosidase, hyaluronidase, TAMEase, BAEEase, and L-amino acid oxidase activities.

Fraction I, obtained by Con A chromatography, was pooled, lyophilized, and then desalted with Sephadex G-10. Fractionation of this desalted nonglycoprotein fraction by ion exchange chromatography (DEAE Sephadex A-50) yielded three large fractions and several minor fractions. PhL-A_2 activity was concentrated in the second major fraction (Fig. 2). PhL-A_2 activity (14,000 units/mg) in this fraction was much higher than that of the crude venom (234 units/mg).

The PhL-A_1-containing fraction obtained by chromatography with DEAE Sephadex A-50 was divided into two samples. Even-numbered tubes (42 through 66) were pooled to from one sample while odd-numbered tubes (41 through 67) formed the other sample. These samples, after lyophilization and desalting, were fractionated with Sephadex G-75. In both instances, PhL-A_2 activity (24,400 units/mg) was observed only in the low molecular weight fraction (Fig. 3).

The low molecular weight PhL-A_2 fraction (tubes 16-22) obtained by Sephadex G-75 chromatography was pooled, lyophilized, desalted, and applied to a Sephadex G-50 column. This fractionation yielded a fraction free of the larger molecules (Fig. 4).

Immunoelectrophoresis and disc electrophoresis of crude venom samples indicated a complex mixture of proteins although the PhL-A_2 fraction obtained by the sequence of Con A-Sepharose 4B, DEAE A-50, Sephadex G-75, and Sephadex G-50 chromatography procedures was greatly purified (Figs. 5-8). Close examinations of both types of electrophoresis patterns, however, indicated trace contaminations. These contaminations could be due, in part, to TAMEase and L-amino acid oxidase since the distributions of these enzymes in *A. bilineatus* venom overlap PhL-A_2 after DEAE Sephadex A-50 chromatography (Sifford and Johnson, 1978). At present, work is directed toward purification of large amounts of PhL-A_2 in order that more enzyme characteristics may be obtained.

We thank Dr. Collis Geren for his work with the gel electrophoresis, Dr. L. W. Hinck for his assistance with the immunological procedures, John Ruff for his assistance throughout this work, and Mrs. Alice Chandler for typing the manuscript.

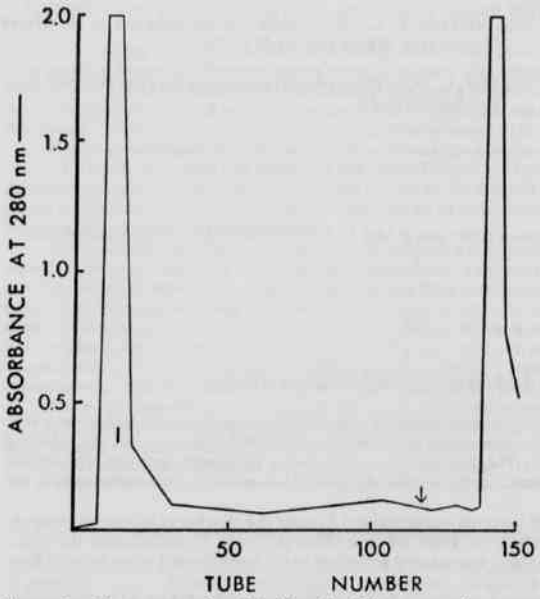

Figure 1. Chromatography of *Agkistrodon bilineatus* crude venom (450 mg) on a Concanavalin A Sepharose 4B column (2.5 × 15 cm) at 4°C by two stage elution. The arrow indicates the start of the second state elution (using α-methyl-D-mannoside). Eluates were collected at a flow rate of 17 ml/hr.

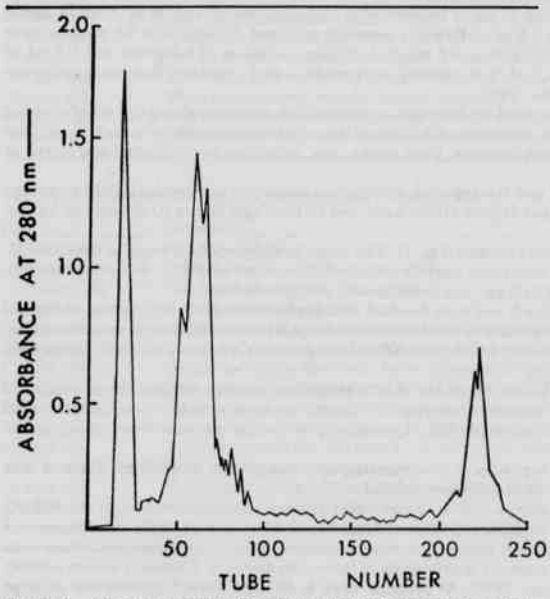

Figure 2. Chromatography of *Agkistrodon bilineatus* venom nonglycoproteins on a DEAE Sephadex A-50 column (2.5 × 56 cm) at 4°C by two stage elution with ammonium acetate buffer. Eluates of 5.0 ml each were collected at a flow rate of 17 ml/hr.

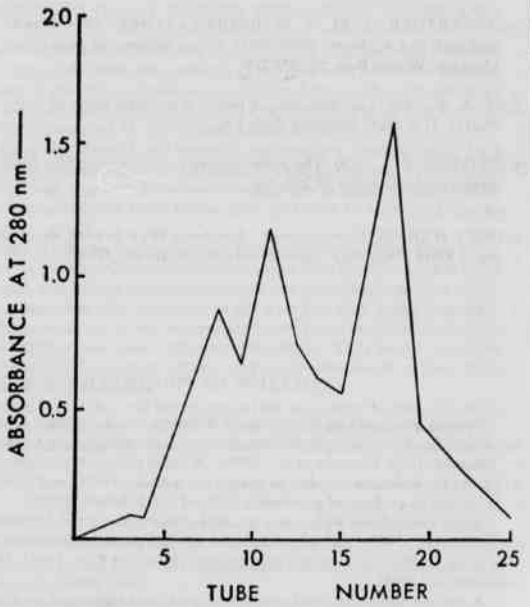

Figure 3. Chromatography of the phospholipase A_2 containing fraction, collected from DEAE A-50 ion exchange chromatography, on a Sephadex G-75 column (1 × 100 cm) at 4°C. Eluates of 4.0 ml/tube were collected.

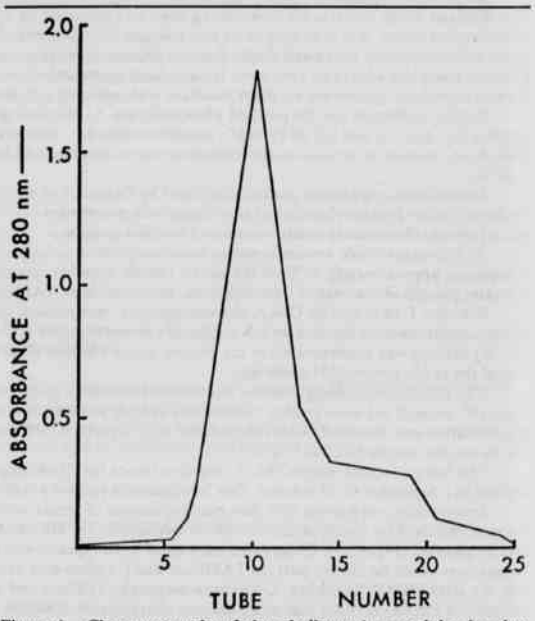

Figure 4. Chromatography of phospholipase A_2 containing fraction, from Sephadex G-75 chromatography, on a Sephadex G-50 column (1 × 100 cm) at 4°C. Eluates of 4.0 ml/tube were collected.

Figure 5. Immunoelectrophoretic patterns obtained by reacting anti-crude *Agkistrodon bilineatus* venom serum with electrophoretically separated crude venom.

Figure 6. Immunoelectrophoretic patterns obtained by reacting anti-crude *Agkistrodon bilineatus* venom serum with electrophoretically separated phospholipase A_2 containing fraction and crude venom.

Figure 7. Immunoelectrophoretic patterns obtained by reacting anti-phospholipase A_2 fraction serum with electrophoretically separated phospholipase A_2 containing fraction and *Agkistrodon bilineatus* crude venom.

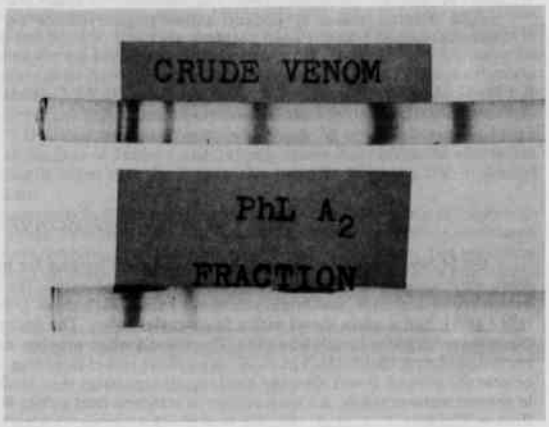

Figure 8. Patterns obtained by Dodecyl Sulfate-Polyacrylamide Gel Electrophoresis of *Agkistrodon bilineatus* crude venom and the phospholipase A_2 containing fraction.

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SAGE THRASHER *(OREOSCOPTES MONTANUS)*, A NEW STATE RECORD

On 24 November 1979, Cheryl Lavers and I were looking for birds in the Farville area, about 6 miles NE of Jonesboro, Craighead County, when we discovered a Sage Thrasher *(Oreoscoptes montanus)*. The bird was rather Mockingbird-like *(Mimus polyglottos)* in shape, plain gray-brown crown and back, and bright yellow eye with a black pupil. Other characters differed from a Mockingbird in that it was smaller and shorter tailed and it had a white throat with a black malar stripe. The underparts, with a ground color of warm buff, were densely streaked with black chevrons arranged in length-wise rows. There was a white wingbar, and a dark tail with white outer corners. The bill was slender, very slightly de-curved, and dark bluish-black in color, as were the rather short legs. The bird ran along the ground in open places, or under brush and stayed on or near the ground. It was observed catching, decapitating, then swallowing ground crickets (*Acheta* sp.). We have both observed Sage Thrashers in several western states. An examination of standard field guides (Peterson, R. T. 1961. A field guide to western birds. Houghton Mifflin Co., Boston; Robbins, C. S. et al. 1966. Birds of North America. Golden Press, N.Y.) further confirmed our identification. A description and slides of the bird have been sent to Charles Mills, Curator, the Arkansas Audubon Society, and Dr. Douglas James, Department of Zoology, University of Arkansas at Fayetteville. This is a first recorded instance of the Sage Thrasher in Arkansas.

In its normal range, the Sage Thrasher breeds in the sagebrush *(Artemisia)* deserts of western North America, coming as far east as western Oklahoma. It winters in the southern part of its range and Mexico, occurring as far east as central and southern Texas, with a small isolated winter colony in extreme southwestern Louisiana (A.O.U. check-list of North American birds, 1957). The species is seldom recorded as a vagrant. The following extralimital occurrences to the east of its range have been recorded: Florida, 2; Illinois, 2; Maryland, 1; New York, 2; North Carolina, 1; South Dakota, 1.

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SOME EFFECTS OF METHYL GREEN ON EXPRESSION OF DAMAGE INDUCED IN G1 *XENOPUS* CELLS BY ULTRAVIOLET LIGHT

Methyl green shows a high degree of specificity for DNA and is a component of many nuclear stains. Kurnick (1952) observed that this basic dye was readily bound by polymerized DNA; two amino groups of the dye binding to two phosphoric acid groups of DNA. Errera (1951) demonstrated that the affinity of DNA for methyl green is influenced by radiation and other agents which depolymerize DNA, or alter its internal configuration. Doudney and Haas (1958) showed that methyl green significantly influenced metabolic activities, such as DNA and RNA synthesis, in *Escherichia coli*. These results suggested that appropriate experiments, involving methyl green treatments coupled with germicidal UV exposures, might aid in describing the expression and repair of UV-induced lethal and mutational damage in prokaryotic cells. Experiments of this nature were carried out by investigators, such as Witkins (1961), which led to the notion that UV induces lesions in bacterial DNA that either are removed by repair systems or are converted to permanent structural changes during the first DNA synthetic period following the exposure. We report here an extension of such experiments to eukaryotic cells, in which some effects of methyl green on the repair of UV (254 nm)-induced damage in G1 phase *Xenopus* cells are examined.

Routine maintenance of log phase A8W243 *Xenopus* cultures, incubations, cell synchronizations, irradiations, mitotic index determinations, survival determinations (colony counts), and chromosome analysis have been described in detail (Griggs and Bender, 1973; Payne and Griggs, 1977; Griggs and Orr, 1979).

The basic dye used, methyl green, was obtained from Difco.

Figure 1 shows results of a series of mitotic index experiments performed to examine the effects of methyl green on progression of UV irradiated G1 cells through interphase and the first succeeding mitosis, (M1). These data described the appropriate time intervals for collection of the sets of mitotic cells analyzed for effects of methyl green on UV-induced aberration production (Table 1). Concentrations of the dye in the range 0.0 - 0.003 g/1 appeared to induce little delay in progression of the irradiated cells above that induced by the UV alone. The similarity in average height and width of these mitotic peaks indicated that the dye did not significantly reduce the number of irradiated cells that reached G1.

The average cell cycle for non-irradiated *Xenopus* cells was approximately 26 hours (not shown); eight hours G1, 13 hours S, three hours G2, and two hours M1. Payne and Griggs (1977) carried out autoradiographic studies which indicated that early G1 phase cells, exposed to low doses of UV (0 - 150 ergs mm^{-2} range), are not delayed in their progression through G1, but experience rather lengthy S phase delays. These facts, coupled with the data of Figure 1 and Table 1, indicate that chromatid aberration frequencies, resulting from UV exposure of early G1 cells, are significantly altered by methyl green only when the dye is in contact with the exposed cells as they pass through early S phase. Some relationship between the aberrant intracellular mechanism, by which methyl green augments chromatid type aberration production, and DNA synthesis is suggested by the fact that both mechanisms appear to function with peak efficiency in early S phase.

The data of Figure 2 indicate that a methyl green concentration of 0.003 g/1 has virtually no effect on the expression of UV-induced lethal damage, no matter where in the cell cycle the dye is applied. These data suggest that the mechanism which expresses UV-induced aberrational damage in *Xenopus* cells differs significantly from the mechanism which expresses lethal damage, supporting results of previous studies of the overlap of UV-induced lethal and aberrational lesions in *Xenopus* cells (Griggs and Orr, 1979; Payne and Griggs, 1977).

Consideration of the data associated with the 0, 8, and 10 hr points of Table 1 suggests that the marked increase in chromatid aberrations observed could have resulted from methyl green inhibition of an early S phase mechanism which repairs UV-induced damage (possibly pyrimidine dimers) in DNA that leads to chromatid aberrations. A previous study (Griggs and Bender, 1973) has shown that UV-induced pyrimidine dimers in the DNA of G1 *Xenopus* cells lead to chromatid aberrations. Both UV-induced dimers and chromatid aberrations in *Xenopus* cells appear to be removed by enzymatic photoreactivation (PR). Furthermore, pyrimidine appears to be the only substrate for PR enzyme. Thus, if the mechanism inhibited by methyl green decreases aberration frequencies by repairing UV-induced dimers, an appropriate PR treatment applied in conjunction with the UV and methyl green treatment should reduce the methyl green effect. Table 2 contains results of one attempt to explore this notion. Immediately after the cultures of early G1 cells were exposed to 90 ergs mm^{-2} UV, they were photoreactivated with the doses indicated and then incubated in methyl green until fixed for chromosome analysis. Comparison of the data of Tables 1 and 2 clearly shows that chromatid aberration frequencies resulting from UV + PR + methyl green treatment are significantly lower than the frequencies resulting from the UV + methyl green treatment, and reduction in aberration frequency is dependent on PR dose.

The present study is far from conclusive and further experimentation is certainly indicated. Nevertheless, we feel that the data strongly suggest the existence of a dark (non-PR) radiation repair mechanism in early S phase *Xenopus* cells. This mechanism is probably closely associated with DNA synthesis and capable of repairing a significant fraction of the UV-induced lesions that lead to chromosomal aberrations. The operation of such a mechanism would tend to explain results of previous studies indicating that doses of UV between 0 and 90 ergs mm^{-2}, which kill from 0-80 percent of the *Xenopus* cells exposed, do not produce aberration frequencies above control levels (Griggs and Orr, 1979). Research supported by National Cancer Institute Grant CA-18809-03.

Table 1. Effects of methyl green on aberration frequencies resulting from a UV exposure of 90 ergs mm^{-2} to early G1 phase cells.

concentration of methyl green (gms per liter)	time methyl green added to cultures (hrs after UV)*	time range over which mitotic cells collected (hrs after UV exposure)	number cells scored	chromatid aberrations: deletions	chromatid aberrations: exchanges	chromosome aberrations: deletions	chromosome aberrations: exchanges
0		55-75	500	4	2	2	1
.003	0	55-80	500	62	33	1	1
.003	8	55-80	500	67	31	2	2
.003	10	55-80	500	47	28	1	1
.003	14	55-80	500	18	7	2	0
.003	20	55-80	500	5	1	2	0

*Methyl green was added to the cultures at the times indicated and not removed until mitotic spreads were prepared for chromosome analysis.

Table 2. Effects of methyl green on aberration frequencies produced in early G1 phase cells by exposures of 90 ergs mm^{-2} UV, followed by varying doses of PR light.

concentration of methyl green (gms per liter)	time methyl green added to cultures (hrs after UV)*	PR dose (ergs mm^{-2})**	time range over which mitotic cells collected	number cells scored	total chromatid aberrations	standard error
0		0	55-80	500	5	0.224
0		$4x10^3$	25-35	500	8	0.258
.003	0.0	0	55-80	500	64	4.314
.003	0.0	$1x10^3$	33-42	500	62	2.771
.003	0.0	$2x10^3$	29-40	500	34	1.521
.003	0.0	$4x10^3$	24-33	500	23	0.994
.003	0.0	$4x10^3$	25-35	500	23	1.030

*Methyl green was added to the cultures at the times indicated and not removed until mitotic cells were prepared for chromosome analysis.
**Cultures received the indicated doses of PR light immediately after UV exposures, before methyl green was added to the cultures.

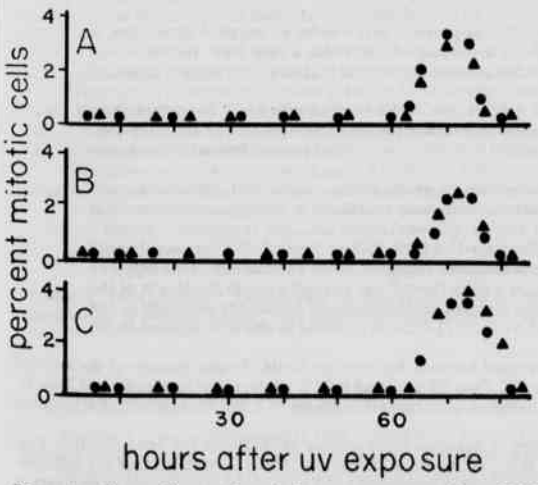

Figure 1. Some effects of methyl green on progression of UV irradiated early G1 cells through interphase and the first succeeding mitosis. Synchronous cultures were exposed to 90 ergs mm^{-2} UV one hour after mitotic selection. A (circles) represents UV alone. In the other experiments, the following concentrations of methyl green were added to the cultures immediately after UV exposure; A (triangles) 0.001 g/1, B (circles) 0.002 g/1, B (triangles) 0.003 g/1, C (circles) 0.004 g/1, C (triangles) 0.005 g/1. The dye remained in the cultures until the experiment was terminated.

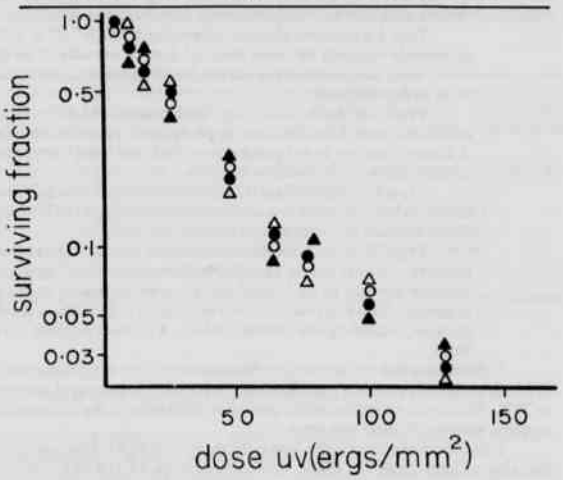

Figure 2. Some effects of methyl green on survival of UV irradiated G1 cells. Synchronous cultures of early G1 cells were exposed to the indicated doses of UV one hour after mitotic selection. The open circles represent UV alone. In the other experiments, methyl green (0.003 g/1) was added to the cultures at the following times after the UV exposures; 0 hours (open triangles), 10 hours (filled triangles), 16 hours (filled circles). The dye remained in the cultures until the experiment was terminated.

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HEMOGREGARINES IN THE RED-EARED SLIDER, *CHRYSEMYS SCRIPTA ELEGANS* (WIED) FROM ARKANSAS

Twenty-five red-eared sliders, *Chrysemys scripta elegans* (Wied), were examined for hemogregarines. Turtles were purchased in late October, 1979 and early May, 1980 from Anderson's Minnow Farms, Lonoke County, Arkansas (T.1N, R.9W, Sec. 35). Blood samples (2.0 ml) were obtained by puncturing the heart with a 21 gauge needle fitted on a 10 ml syringe. Thin blood smears were air dried, fixed in absolute methanol for 2-3 minutes, stained with Giemsa for 25 minutes, dipped briefly in buffered water (pH 7.0 @ 25°C) and allowed to dry. Blood smears were examined under oil immersion and infected erythrocytes were located to avoid the possibility of confusing ex-erythrocytic forms of the parasite with normal blood cells, especially young thrombocytes. The staining characteristics, cytoplasmic characteristics, and general shape and form of the parasitic forms were noted. Measurements were taken with an eyepiece micrometer. No attempt was made to study the tissue stages of the hemogregarines through histological preparations.

All of the *C. s. elegans* examined were infected with intraerythrocytic forms. Parasitemias ranged from approximately 0.5 percent of the erythrocytes in one turtle to barely detectable infections in the majority of the turtles. Following a conservative strategy, no attempt was made to relegate parasitic forms to particular life cycle stages. Rather, individual forms were assigned to one of four morphological types as follows (measurements in micrometers [μm], the range follows in parentheses):

Type I is crescent shaped, measuring 8.9 (9.8-7.8) × 2.3 (2.9-2.0). The parasite, as is true for all morphological types, is apparently encased by some form of cyst or vacuole. The cytoplasm is flocculated and stains a light blue. Inclusions are rarely seen, and a nucleus is not readily discernable. The nucleus of the invaded erythrocyte is at most only slightly displaced from its normal position.

Type II is characteristically "bean shaped" 13.4 (14.1-12.7) × 4.2 (4.9-2.9), with a short recurved tail. The cytoplasm is somewhat more basophilic and appears more dense in some specimens. Acidophilic inclusions are common in the cytoplasm. A distinct nucleus is not generally evident, but a dark irregularly shaped structure is sometimes present instead. The parasite usually displaces the nucleus laterally.

Type III parasites are 13.6 (14.1-12.7) × 5.6 (6.8-3.9) and vary from "bean shaped" to nearly oval. Cytoplasmic and nuclear characteristics are similar to those of Type II. The acidophilic inclusions are prominent in this type, and the nucleus of the invaded cell is displaced toward one end.

Type IV is the most distinctive of the morphological types. The large 17.5 (19.5-15.6) × 5.9 (7.8-4.9) "banana-shaped" parasite occupies nearly all of the turtle erythrocyte. The erythrocyte nucleus is displaced to the extreme end of the cell. The parasite appears to be formed by two arms or bodies at the ends, as a clear "canal" or "groove" extends the length of the organism. The flocculated cytoplasm stains a light blue. Acidophilic granules characteristically border the periphery of the parasite, including the central "canal". A distinct nucleus 6.0 (6.8-5.9) × 2.2 (2.9-2.0) is apparent in one arm adjacent to the bend.

A determination of the relative frequencies of the morphological types could be made for only one turtle. Twenty percent of the infected erythrocytes contained the Type I parasite. Twenty-nine percent carried Type II. Type III occurred in 21% of the parasitized cells, and Type IV in 30%. There was no statistically significant difference in the occurrence of morphological types (Chi square = 3.28). No evidence of schizogony or other nuclear division was seen.

This report represents the first published record of a hemogregarine from an Arkansas turtle species. Mohammed and Mansour (Bull. Fac. Sci. Cairo Univ. 35:39-51, 1959); Ball (J. Protozool. 18:198-210, 1967); Ball et al., (J. Parasitol. 53:897-909, 1967) have stated that the establishment of the taxonomic status of hemogregarines at both the generic and specific levels is dependent upon a thorough examination of all stages of the life cycle in both the vertebrate and invertebrate hosts; however, in the absence of such data, the exact determination of the taxonomic status of hemogregarines in Arkansas turtles awaits further study.

The authors thank Dr. James J. Daly, University of Arkansas for Medical Sciences, for reviewing representative slides.

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OBSERVATIONS ON THE INCIDENCE OF CHIGGERS, *EUTROMBICULA ALFREDDUGESI* (OUDEMANS) ON *CROTAPHYTUS* (SAURIA:IGUANIDAE) IN IZARD COUNTY, ARKANSAS

During an ecological investigation of the eastern collared lizard, *Crotaphytus collaris collaris*, data were obtained on the incidence of ectoparasites infesting this lizard at an abandoned rock quarry in Izard County, near Myron, Arkansas (T.18N, R.7W, Sec. 26).

Collared lizards emerging from hibernation in early April, 1979, were free of ectoparasites, and remained so until June. Infestation by chiggers (larval trombiculid mites) extended from June through October, with the greatest density in July (Fig. 1). Sixty-seven chiggers were identified and found to be *Eutrombicula alfreddugesi*. Eleven (27%) of 41 lizards were infested with *E. alfreddugesi*. The majority of chiggers were attached under scales on the nuchal folds, on folds around the axilla, and near the post-femoral pockets and ear openings, with 13 found near the cloaca. Other lizards collected near the study site which were infested with *E. alfreddugesi* included: *Eumeces fasciatus*, *Eumeces laticeps*, and *Sceloporus undulatus*.

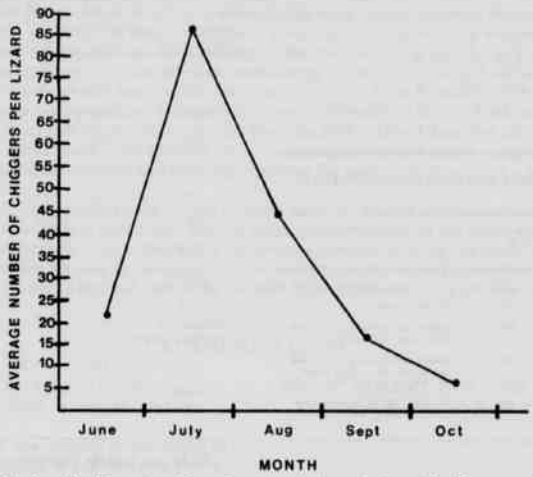

Figure 1. The occurrence of *Eutrombicula alfreddugesi* on *Crotaphytus collaris collaris* at the Myron study site, from June through October 1979.

Distribution of trombiculid mites is known to be localized and sporadic and may not be constant throughout a particular study area (Baker, et al., Natl. Pest Control Assoc. Tech. Pub., New York, 170 pp, 1956; Allred and Beck, Herpetologica 18:47-50, 1962; Spoecker, Amer. Midl. Nat. 77:539-542, 1967). At the Myron site, chigger infestation was locally variable, being more closely associated with some plant communities (eg., mixed grasses) than with others.

Wolfenbarger (Ann. Ent. Soc. Amer., 45:645-677, 1952) reported *E. alfreddugesi* from *S. undulatus* in Crawford and Newton counties, Arkansas. To my knowledge, this report represents only the second published record on the ectoparasites of Arkansas lizards.

This investigation is based on a portion of a thesis prepared in partial fulfillment of the requirements for a Master's degree in Biology at Arkansas State University. I thank Dr. V. R. McDaniel for reading the manuscript. Dr. J. O. Whitaker, Jr., Indiana State University, and Dr. R. B. Loomis, California State University-Long Beach, aided in the identification of the chigger mites. I also thank Mr. L. Ferguson for allowing me to carry out the study on his property.

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GROWTH AND YEAR CLASS COMPOSITION OF WHITE BASS *(MORONE CHRYSOPS)* IN DEGRAY LAKE, ARKANSAS

DeGray Lake was impounded in 1969 on the Caddo River, 11.3 km north of Arkadelphia in west-central Arkansas. At normal pool elevation (124.4 m above mean sea level), the lake has an area of 5,427 ha, a maximum depth of 57 m and a mean depth of 15 m.

White bass *(Morone chrysops)* have been important predators and sport fish since 1971, following the stocking of 460 adults in the fall of 1969. We conducted electrofishing surveys on the spawning grounds each spring, 1975-79, to obtain basic information on the population dynamics of this species. Spawning concentrations occurred in the upper end of the lake and extended a short distance upstream in the Caddo River. Spawning usually took place during the last two weeks in March at water temperatures of 12 to 17°C. A total of 550 fish were collected by electrofishing, representing nine year classes (1970-1978). Fish of the 1970 year class were also collected as young-of-the-year in September by biologists of the Arkansas Game and Fish Commission *(unpublished data)*. Length, weight, sex, and maturity were recorded for all fish, and scale samples were taken from most of the fish.

There have been no reproductive failures since 1970. Our collections indicated that strong year classes were established in 1971, 1974 and 1977 (Table 1). However, moderately strong year classes tend to mask the true strength of strong year classes. Year class strength was not correlated with Caddo River inflows during the spawning period.

Mean lengths (sexes combined) for all ages I through VI were 250, 350, 385, 407, 424, and 419 mm, respectively (Table 2). The oldest white bass (419 mm) collected were age VI, and only 15% of all fish collected were older than age IV. Growth of white bass in DeGray Lake was similar to that of other Arkansas reservoirs (Table 3). First-year growth was faster in DeGray Lake; however, age I fish were represented only by sexually mature males that had migrated to the spawning areas. As noted by most investigators, females grew faster than males. Mean length of females at each age was at least 21 mm greater than that of males.

Table 1. Year class composition (percent) of white bass collected in DeGray Lake each spring, 1975-79.

YEAR OF COLLECTION	NUMBER OF FISH	YEAR CLASS								
		1970	1971	1972	1973	1974	1975	1976	1977	1978
1975	95	2.1	64.5	14.7	8.4	5.3				
1976	55		12.7	25.5	20.0	38.2	3.6			
1977	92			29.3	12.0	35.9	9.8	13.0		
1978	181			0.5	15.0	27.1	7.7	18.2	31.5	
1979	127				5.5	10.2	22.8	15.7	44.1	1.6

Table 2. Average total length (mm, empirical data) of white bass from DeGray Lake, 1975-79.

	AGE AND SEX											
	I 1]	II		III		IV		V		VI		
YEAR CLASS	M	M	F	M	F	M	F	M	F	M		
1978	246											
1977	251	334	357									
1976	243	330	350	357	365							
1975	259	345	366	369	393	390	400					
1974	251	339	351	374	399	384	416	401	435			
1973		343	380	375	408	396	415	417	428	419		
1972				392	415	405	427	420	438			
1971						403	427	415	433			
1970									438			
Unweighted Average Length												
By Sex	250	338	361	373	396	396	417	413	434	419		
Sexes Combined	250	350		385		407		424		419		

Table 3. Average total length of white bass from selected lakes in Arkansas.

WATER	TOTAL LENGTH (MM) AT END OF YEAR OF LIFE				REFERENCE
	I	II	III	IV	
DeGray Lake	250 1]	350	385	407	Present Study
Lake Catherine	224	305	333	368	Hulsey and Stevens, Proc. Ark. Acad. Sci. 12:17-30, 1958.
Bull Shoals Reservoir	190	332	382	420	Houser and Bryant, U. S. Fish and Wildl. Serv. Tech Paper No. 40, 11 pp., 1970.
Beaver Reservoir	216	295	355	385	Velleyi, Ph. D. Dissertation Univ. of Ark., 193 pp., 1972.

1] Males only

1] Only one female yearling was collected during the study.

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USE OF AN OUTDOOR LAB IN TEACHING BOTANY

Those of us who teach botany with an ecological emphasis often have difficulty in locating areas for field experiences for our classes. At the University of Central Arkansas, however, the Outdoor Lab is an ideal setting for such exercises. This Outdoor Lab is situated on the southwestern part of the campus and consists of these habitats: a wooded area, an old field or pasture (perhaps a "prairie remnant"), shrubby successional stages, and a stream. This Outdoor Lab is considered part of the UCA Campus Arboretum (Moore, 1974).

At the present time four laboratory-field exercises have been developed and are being regularly used with my General Botany classes.

The first field experience is for consciousness-raising and is primarily set up to develop an awareness of the natural plant community. The class assembles at a circle of benches set up in the midst of the wooded area. A brief introduction to the area is given—the history of its development and its function on campus. Members of the class are then given suggestions for "experiencing an ecosystem." No communication with peers or instructor is permitted. Each student is instructed to wander in the area at will or sit to listen to sounds, to see what can be seen, to smell, to feel textures of rock or bark or leaf—letting thoughts come and go at will, recording in sketches or words, or not recording, as it pleases the student. At a signal from the instructor, the group gathers back at the benches to share reactions from this experience (if they wish to do so). Discussion follows and leads into consideration of the types of organisms seen in the area; some concepts of the ecological relationships are introduced to the group. These relationships deal with the basic ecological classification of organisms into decomposer, producer, and consumer categories. Listing of those seen by members of the class (perhaps pointing out some of these, if unnoticed by the group) tends to focus thoughts on some of the ecological concepts which will later be discussed in their text.

A second lab experience deals with the decomposers—a group of organisms which tends to be under-studied in most field experiences dealing with plant communities. Near the wooded area is a place where the maintenance crew dumps leaves and other biodegradable materials from campus clean-ups. Examination of what is happening in this large "compost pile" leads naturally into discussions of cycling of materials and energy in ecosystems. Discussions dealing with organisms involved, processes of metabolism, end-results, availability of materials and energy, and related questions can become quite lively and productive. Questions dealing with decomposition of organic materials, or composting, include: Does the decomposition of certain kinds of leaves (oak, pine, maple, elm) change the pH of the soil? How long does decomposition take? Is the process speeded by use of commercially available preparations? Can chemical fertilizers be used? Are aerobic or anaerobic conditions "better"? Students can usually add many questions, and they contribute to designing experiments by which some of these questions can be tentatively

answered. The fact that these experiments usually use containers which are being recycled (such as half-gallon milk cartons) adds to the development of the concept of recycling. Setting up these experiments which they have designed has enabled these students to apply the scientific method of investigation to a problem in which they are interested, and recycling materials and energy has been emphasized. If the group can be encouraged to see the value of recycling other materials such as aluminum cans and see some glimpse of the relationship of such recycling to plants and plant communities, then more of the total material-energy picture can be included in discussions.

The third Outdoor Lab experience deals with the traditional sampling methods by which plant communities can be described. The botany students have had some experience in keying out trees on other parts of the campus arboretum, using Moore (1972); hence, they are able to identify the trees within the wooded area of the Outdoor Lab rather quickly. During the laboratory period, the modified point-quarter method (Smith, 1980) is used in sampling of the trees. The plant community is named in terms of the importance values assigned to the trees, a value based on the percentages of dominance, frequency, and density of the trees. Discussion of other sampling possibilities enables the students to form some concepts dealing with the techniques of quantifying other aspects of the ecosystem.

During the fourth session, the emphasis is on the time-space relationships of this plant community with others. Succession is observed in the various seral stages present in a proposed Nature Reserve, an area extending beyond, yet included in the Outdoor Lab area. Back at the bench circle, a discussion of relationships in time and space of these examples of plant communities with the worldwide view is usually quite rewarding. This discussion includes looking at a sheet dealing with activities relating to lifestyle, including hobbies and work, as these activities relate to the environment (in terms of polluting or maintaining it), to the economy and energy (in terms of cost and use of materials and energy), and to each student. Hopefully, the discussion which follows will spark some questions dealing with each student's relationship to the whole and thoughts concerning the student's reactions to these basic problems. Is the grassy community really "a prairie remnant"? If so, does that make it more valuable as part of a Nature Reserve or Outdoor Lab for the UCA campus? How can it be preserved and yet used to best advantage? Should students be concerned about the environment? about plant communities? about recycling materials? about energy shortages and alternative sources? These questions, hopefully, change to the more valuable and life-long questions for each student: What concerns do I have about these things? and what can I do about these concerns?

Having the Outdoor Lab on the UCA campus has been a most valuable asset for teaching these ecological concepts to various classes. With the increased emphasis on environmental education in our state and the development of outdoor-lab facilities in the various public school systems in Arkansas, it becomes even more important that the colleges and universities develop such on-site facilities for students. Students in general, not just the botany students, need to receive training in environmental awareness, to develop a knowledge of some of the relationships and dependencies on our "Spaceship Earth", in order to become part of the solution to problems and not part of the problems.

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AN INVESTIGATION OF THE STREAMBED OXYGEN DEMAND OF FOURCHE CREEK, PULASKI COUNTY, ARKANSAS

In recent years Fourche Creek has been the site of numerous investigations (ADPC&E, 1974a,b; Bryant and Terry, 1979; U.S. Army CoE, 1972). The stream has a history of consistently low D.O. values. Previous five-day BOD's collected indicated that neither the carbonaceous nor nitrogenous demand, nor a combination of the two, was sufficient to account for the low D.O. concentrations measured (ADPC&E, 1974a).

In a modeling report by Bryant and Terry (1979), it was hypothesized that the benthic deposits exerted a significant demand on the oxygen in the overlying water. The primary purposes of this study were to compare S.O.D. values derived experimentally with those derived from the model and, if possible, define the effects on the stream's ecosystem.

Fourche Creek extends 30 miles (48.6 km) from its sources in northeastern Saline County, Arkansas, to its confluence with the Arkansas River in Pulaski County. The sources lie in the eastern edge of the Ouachita Mountains at an elevation approximately 600 feet above mean sea level (Fig. 1). Figure 2 is a schematic diagram of the Fourche drainage showing locations of tributaries and major municipal and industrial effluents relative to its confluence with the Arkansas River. The main stem also receives runoff from springs, timberland, pastureland and residential areas (USACE Environmental Assessment Report, 1972). Table 1 contains data regarding the sampling sites.

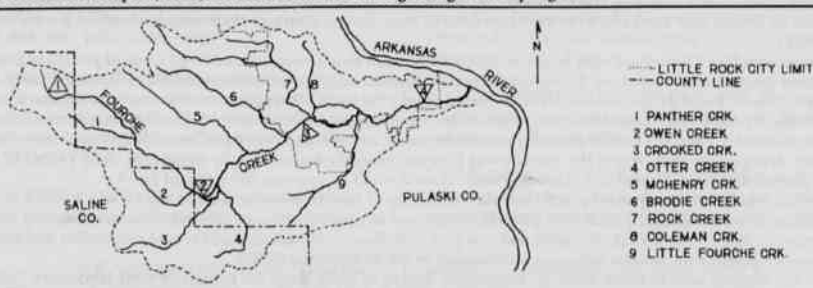

Figure 1. Map of Fourche Creek drainage showing sampling sites and major tributaries.

Table. 1 Sampling sites of Fourche Creek, February-August 1979 (location is distance upstream from its confluence with the Arkansas River.

Site	Location	Substrate	Mean Depth (m)	Mean Width (m)
1	46.2 km	sand, gravel, cobble, some bedded shale and quartz	0.1	5.5
2	33.2 km	cobble, boulders, some sand, heavy vegetation	0.1	6.8
3	19.4 km	silt and sand layered with detritus	0.09	8.3
4	7.3 km	silt and sand layered with detritus, some oils	0.6	5.2

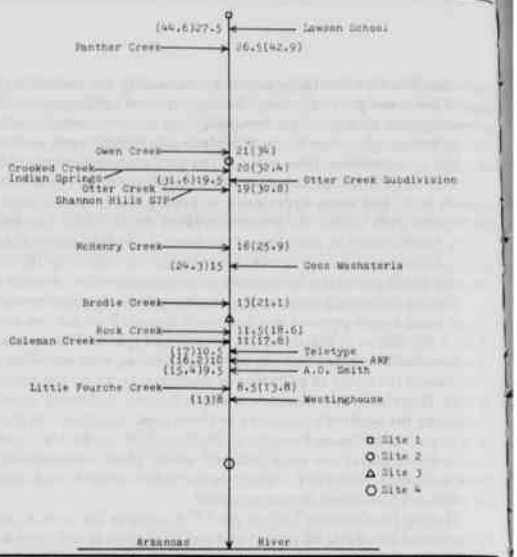

Figure 2. Schematic of Fourche Creek drainage indicating the major tributaries and waste effluent sources. Numbers are miles (km) from the confluence with the Arkansas River.

For each sampling period, pH, specific conductance, D.O. and water temperature were determined in the field according to the methods given in USGS (1979). In addition to the collection of field parameters, surface water and sediment samples were collected, chilled and taken to the laboratory for analyses. Water samples were analyzed for fecal coliform and streptococcus bacteria and five-day BOD. The sediment was measured for COD, total kjeldahl nitrogen (ammonia plus organic nitrogen), total ammonia nitrogen, total nitrate and nitrite nitrogen and total phosphorus. All laboratory procedures were in accordance with USGS (1979).

In addition, minimal disturbance sediment samples were collected and analyzed for S.O.D., which is defined as the D.O. uptake from the overlying water by benthic materials and/or organisms. The demand results mainly from the reduction of biologically oxidizable material and the respiration of micro- and macro-organisms, but inorganic chemical oxidation reactions may also contribute to the demand. The major micro-demand is generally due to bacterial and fungal respiration, whereas the macro-demand is by both surface-dwelling and burrowing organisms (Butts and Evans, 1977). Periphyton may also contribute significantly in some aquatic environments.

Several methods to measure S.O.D.'s are available (Bowman and Delfino, 1978); however, the technique outlined by Nolan & Johnson (1977) was used in this study. This technique involves carefully removing the top 5-8 cm of bed material, transporting it with minimal disturbance to the laboratory and placing it in a closed-system respirometer. The sediment in the S.O.D . chamber was 2.5 cm deep with 0.069 m^2 of surface, and 24 l of unbuffered aerated, demineralized water was circulated through the system with a peristaltic pump. Dissolved oxygen was recorded as the system was operated at 21 ± 2°C for 24 hours. The part of the curve where oxygen consumption versus time was constant was used for calculating the S.O.D. rate. A control was run without sediment and the correction made in the calculation. One to three samples from each site and date were run, and to reduce individual variation, the mean value of each series was used as the S.O.D. during that sampling period.

Individual S.O.D. measurements are given in Table 2, and mean S.O.D. values and other parameters are given in Table 3. The variation in values was probably due in part to the disturbance of the sediment during collection and filling of the respirometer. Some variation may also be attributed to natural variation in sediment composition patterns. One would expect slight variation at a given site, more at different sites on a stream and still more between streams. Butts and Evans (1977) determined that S.O.D. values vary greatly among streams. After studying several streams in Illinois, they estimated values of 0.27 g/m^2/day for relatively clean streams to 9.3 g/m^2/day for heavily polluted streams.

Fourche Creek has a history of low oxygen concentration (Fig. 3). Water quality data collected during this study (Table 3) support the ADPC&E (1974a) findings that whole-water components were not the primary cause of the low D.O. values. The stream had a moderate pH (6.8 to 7.4) with the exception of pH 7.8 at Site 1 on 20 March. Low alkalinity (ADPC&E, 1974a) and conductance values (Table 3) indicate a relatively unbuffered system.

Five-day BOD values between two and five should not have a significant demand on the stream's D.O. Neither the bacterial counts nor the nitrogen and phosphorus values are unusually high. Low trace metal concentrations (ADPC&E, 1974b) should minimize the inorganic chemical oxidation reactions. Thus, the measured wasteloads do not account for the low D.O. values.

Sediment samples collected during this study (Table 3) indicate that deposited material is the major contributing factor in the D.O. sag as was hypothesized by Bryant and Terry (1979) in the calibration of their model, although their estimated values were somewhat higher than those actually measured.

Downstream from Site 2 Fourche Creek begins to meander, the fall rate decreases, and large areas of pools are present. As the velocity decreases, reaeration decreases and sediment deposition increases. Bottom organics and sediment COD's increased more than ten times within an eight-mile (13 km) reach (Table 3). Sediment COD's increased from 2500 to 99,500 mg/kg whereas the total bottom kjeldahl nitrogen increased from 160 to 1770 mg/kg during the August sampling. Within this same reach the D.O. concentration decreased from 9.1 to 4.0 mg/1 (Fig. 3). The high D.O. values at miles 5.0 and 0.5 in 1979 probably are not representative of the lower Fourche because the points of measurement were at the confluence of two dredged channels where the velocity was high and reaeration undoubtedly significant. Fifty yards (46 m) upstream from Site 4 the stream was pooled, and the sediment was black silty sand. Here the S.O.D. rate was twice that at Site 4.

The ADPC&E report (1974b) showed a small population density of benthic invertebrates at Sites 2 and 3 which probably could not exert a heavy S.O.D. Since several chemical parameters generally increased in concentration or intensity downstream, and bacterial counts increased (with the exception of Site 1), the S.O.D. probably was due to a combination of bacterial and fungal respiration and oxidation of organics with, perhaps, the organics exerting the greater influence as indicated by the downstream COD's.

The authors wish to thank the U.S. Geological Survey in Little Rock for the use of their laboratory facilities and collecting equipment.

Table 2. S.O.D. rates ($g/m^2/day$) in Fourche Creek, Pulaski County, Arkansas, 1979.

Date	Site 1	mean	Site 2	Mean	Site 3	Mean	Site 4	Mean
13 Feb	1.27							
	1.87							
	2.47	1.87						
16 Feb			2.65					
			1.19					
			1.37	1.74				
17 Feb					1.38			
					1.96	1.67		
20 Mar	1.58							
	1.87	1.72						
13 Jul							1.61	1.61
17 Jul					2.55	2.55		
1 Aug	2.24							
	0.50							
	1.67	1.47						
3 Aug			0.83					
			1.82	1.32				
17 Aug							3.35	
							3.10	3.22

Table 3. Water quality data for Fourche Creek, Pulaski County, Arkansas, 1979.

	Site 1			Site 2		Site 3		Site 4	
	Feb 13	Mar 20	Aug 1	Feb 16	Aug 7	Feb 17	Jul 17	Jul 13	Aug 17
pH	7.4	7.8	---	7.5	7.4	6.8	6.9	7.0	---
Temperature (°C)	3.0	---	---	7.0	---	5.0	26.0	25.5	---
D.O. (mg/l)	12.8	---	---	11.6	---	12.6	4.8	3.7	---
Specific Conductance (umhos)	111	239	200	98	103	82	92	120	---
Sediment C.O.D. (mg/kg dry wt.)	4100	---	2500	---	2700	13000	99500	36500	---
5-day B.O.D. (mg/l)	1.6	2.8	3.9	2.0	1.2	1.3	3.0	5.0	---
Mean S.O.D. ($g/m^2/d$)	1.87	1.72	1.47	1.74	1.32	1.67	2.55	1.61	3.22
Fecal Coliforms (colonies/100 ml)	1800[a]	4400[a]	---	22[a]	78[a]	500	290	1100	---
Streptococci (colonies/100 ml)	1100	1200[a]	---	10[a]	---	120	310	360	---
Sediment TKN (mg/kg of N)	3.2	---	170	---	160	1000	1770	260	---
Sediment NH_3-N (mg/kg of N)	2.3	---	0.0	---	0.0	12	6.9	0.0	---
Sediment NO_3-N (mg/kg of N)	0.0	---	3.9	---	0.0	0.0	4.6	3.6	---
Sediment P (mg/kg of P)	---	---	430	---	88	---	450	540	---

[a]Estimate.

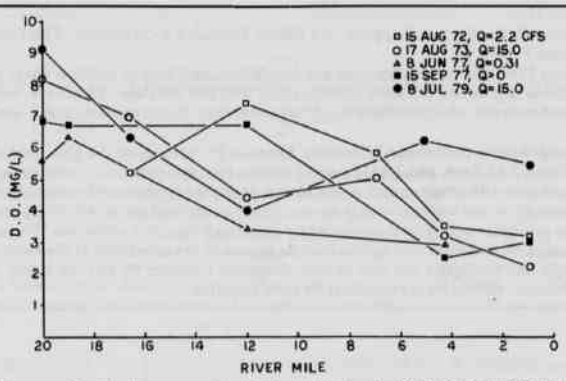

Figure 3. Summer dissolved oxygen values in Fourche Creek, 1972-1979. (ADPC&E, 1974a,b)

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A GLYCOPROTEIN PROTEINASE IN *AGKISTRODON BILINEATUS* VENOM

Snake venoms are noted for their wide variety of proteolytic enzymes. The Mexican mocassin *Agkistrodon bilineatus* is a pit viper whose crude venom is no exception (Sifford and Johnson, 1978). The goal of this work was to determine if *A. bilineatus* venom contains glycoprotein proteases.

Assay procedures for protease, phosphomonoesterase, phosphodiesterase, 5'-nucleotidase, phospholipase A_2, N-benzoyl-L-arginine ethylesterase (BAEEase) and p-toluenesulfonyl-L-arginine methylesterase (TAMEase), thrombin-like, L-amino acid oxidase and NAD nucleosidase were the same as those used in previous works (Sifford and Johnson, 1978; Brunson et al., 1978). Hyaluronidase activity was measured by the turbidimetric method of Kass and Seastone (1944).

Separations of crude venom into proteins positive to the anthrone reagent (glycoproteins) and nonglycoproteins were performed using Concanavalin A (Con A) covalently bound to Sepharose 4B gel as described by Iscove et al. (1974) and Aspberg and Porath (1970). The glycoprotein fraction was desalted with a column (1 × 90 cm) of Sephadex G-10 at 4°C. This desalted fraction was lyophilized and then fractionated by ion exchange chromatography (DEAE Sephadex A-50). In this procedure the methods of Cheng and Ouyang (1967) and Ouyang et al. (1971) including the modifications by Sifford and Johnson (1978) were used. Sephadex G-100 at 4°C was then used to separate molecules according to their molecular weight. Dodecyl Sulfate-Polyacrylamide Gel Electrophoresis separations were performed by Dr. Collis Geren, University of Arkansas at Fayetteville, according to the procedures outlined by Weber and Osborn (1969).

Antisera in New Zealand white rabbits were developed according to Ownby et al. (1979). Immunoelectrophoresis procedures (Campbell et al., 1963; Buchler Instruments Manual, 1964; Garvey et al., 1977) were used to determine the purity of the glycoprotein protease enzyme.

Fractionation of the crude venom with Con A yielded two fractions; Fraction I composed of nonglycoproteins and Fraction II composed of glycoproteins (Fig. 1). The glycoprotein content of the crude venom was calculated as 17.4%. Enzyme activities of Fraction II were determined. Mean enzyme-specific activities included 11.79 μmoles/min/mg for phosphomonoesterase; 3.54 μmoles/min/mg for phosphodiesterase; 83 units/mg for phospholipase A_2; 2.0 μmoles/min/mg for 5'-nucleotidase; 0.01 PU^{gas}_{mg} for protease; 66 TRU and 332 NF units for hyaluronidase; 0.04 units/mg for NADase; 70 units/mg for BAEEase; 20 units/mg for TAMEase; and 1.5 μoles/hr/mg for L-amino acid oxidase. Thrombin-like activity was not observed in Fraction II.

Fraction II was pooled, lyophilized, desalted, and applied to a DEAE Sephadex A-50 column. This fractionation yielded several minor fractions and one major fraction, Fraction P_1 (Fig. 2).

Protease activity was present in Fraction P_1. This fraction was lyophilized and 5 ml of distilled water added. Fractionation of 1 ml aliquots with Sephadex G-100 yielded a fraction (P_2) having protease activity along with low NADase, TAMEase, and BAEEase activities (Fig. 3). Assays for phosphomonoesterase, phosphodiesterase, phospholipase A_2, 5'-nucleotidase, hyaluronidase, and L-amino acid oxidase in the fraction were negative.

Disc electrophoresis of the crude venom produced 12 fractions. Fraction P_2, containing the glycoprotein protease, contained 5 components (Fig. 4). The trace activities of NADase, BAEEase, and TAMEase in Fraction P_2 may account for these discs.

Seven precipitin arcs were produced with crude venom as the electrophoretically separated antigens and with the crude venom antiserum in the trough (Fig. 5). By using Fraction P_2 in one well and crude venom in the other well as the electrophoretically separated antigens and crude venom antiserum in the trough, one precipitin arc (A) was produced by Fraction P_2 and the antiserum. The crude venom antigens again produced seven precipitin arcs (Fig. 6). By using Fraction P_2 in one well and crude venom in the other well as the electrophoretically separated antigens and Fraction P_2 antiserum in the trough, one precipitin arc was produced against Fraction P_2 and the crude venom (Fig. 7). Although this arc is probably due to the glycoprotein protease more data are required for substantiation.

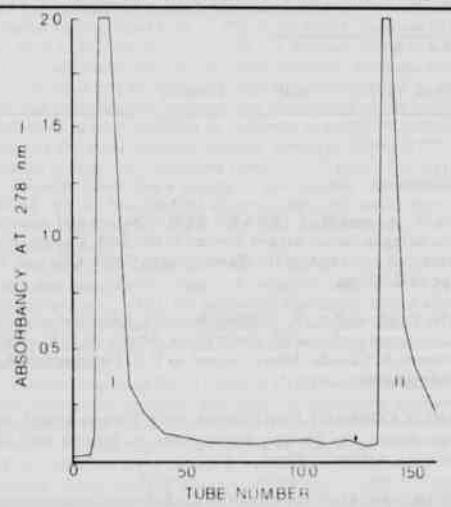

Figure 1. Chromatography of *Agkistrodon bilineatus* crude venom (450 mg) on a Concanavalin A Sepharose 4-B column (2.5 × 15 cm) at 4°C by two stage elution. The arrow indicates the start of the second stage elution (using α-methyl-D-mannoside). Eluates (5 ml/tube) were collected at a flow rate of 17 ml/hr.

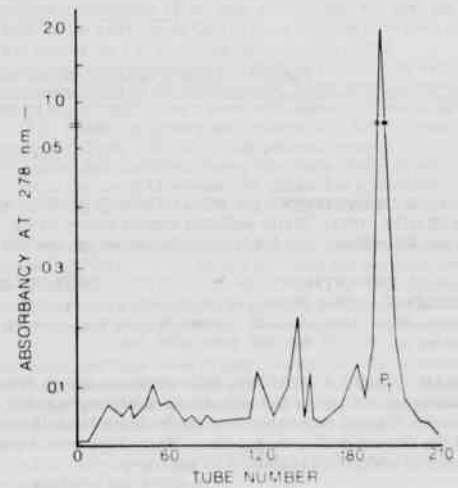

Figure 2. Chromatography of *Agkistrodon bilineatus* venom glycoproteins on a DEAE Sephadex A-50 column (2.5 × 56 cm) at 4°C using an ammonium acetate buffer gradient. Eluates of 5.0 ml/tube were collected at a flow rate of 17 ml/hr.

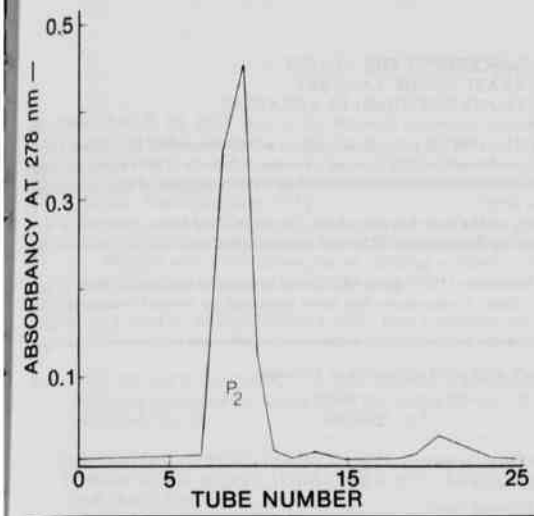

Figure 3. Chromatography of Fraction P_1 (Fig. 2) on a Sephadex G-100 column (1 × 90 cm) at 4°C. Eluates of 4.0 ml/tube were collected at a flow rate of 16 ml/hr.

Figure 4. Comparison of patterns obtained by Dodecyl Sulfate-Polyacrylamide Gel Electrophoresis of *Agkistrodon bilineatus* crude venom and the proteinase containing fraction (P_2).

Figure 5. Composite slide of immunoelectrophoretic patterns obtained by reacting anti-crude *Agkistrodon bilineatus* venom serum with electrophoretically separated crude venom.

Figure 6. Composite slide of immunoelectrophoretic patterns obtained by reacting anti-crude *Agkistrodon bilineatus* venom serum with electrophoretically separated proteinase containing fraction (P_2) and *A. bilineatus* crude venom.

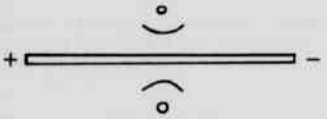

Figure 7. Immunoelectrophoretic patterns obtained by reacting anti-Fraction P_2 serum with electrophoretically separated proteinase containing fraction (P_2) and *Agkistrodon bilineatus* crude venom.

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IMPLICATIONS AND CONSIDERATIONS CONCERNING THE STATUS, HABITAT AND DISTRIBUTION OF THE LEAST BROOK LAMPREY, *LAMPETRA AEPYPTERA* (ABBOTT) (PISCES:PETROMYZONTIDAE) IN ARKANSAS

The least brook lamprey, *Lampetra aepyptera* (Abbott), is described by Eddy (1969) as a small lamprey in small streams of the upper Ohio River drainage, from the Potomac to Neuse River drainages along the east coast, and in some Gulf Coastal streams. Schwartz (1959) reported that the species in West Virginia is apparently more confined to small brooks than other lampreys, and Trautman (1957) suggested that spawning occurs in Ohio in streams less than 4.6 m wide, when water temperature reached 10°C.

The species was reported by Robison (1974) as rare in Arkansas based partly on the fact that only three specimens had been collected in Arkansas at that time. *L. aepyptera* was not included in the Arkansas ichthyofauna by Buchanan (1973), but was included in a list of species most likely to be added to the state species list.

The first record of *L. aepyptera* in Arkansas was collected by Harp and Matthews (1975) from Mill Pond Branch in the South Fork of the upper Spring River, and from Piney Creek in the White River drainage. Since then, *L. aepyptera* has been reported by several researchers in north central Arkansas (Table 1).

Table 1. Recent records of the least brook lamprey, *Lampetra aepyptera* in Arkansas.

CATALOGUE #	DATE	LOCATION	# of SPECIMENS
ASUMZ 1553	27 Jan '73	FULTON CO: Mill Pond Branch	2
ASUMZ 1878	17 Feb '73	IZARD CO: Piney Creek	1
ASUMZ 4484	9 Mar '75	STONE CO: N. Sylamore Creek	2
ASUMZ 5378	10 Mar '75	FULTON CO: Myatt Creek	1
ASUMZ 7891	2 Oct '76	RANDOLPH CO: Eleven Pt. River	1
ASUMZ 8532	25 Feb '78	LAWRENCE CO: Cooper Creek	1
ASUMZ 8892*	16 Mar '79	SHARP CO: Rock Creek	1
NLU 39424	27 Mar '78	SHARP CO: Martin Creek	3
SAU (Uncat.)	4 Apr '75	IZARD CO: Little Strawberry River Tributary	2
SAU (Uncat.)	4 Apr '75	IZARD CO: McJunkins Branch	1
SAU (Uncat.)	4 Apr '75	IZARD CO: Bull Pen Creek	1
SAU (Uncat.)	4 Apr '75	SHARP CO: Big Creek Tributary	3

(*denotes new range extension)

A single 99 mm (TL) male specimen of *L. aepyptera* was collected in Rock Creek, Sharp County, Arkansas (T.18N, R.4W, Sec. 4) during routine electroshocking operations on 16 March 1979. The collection site was a rocky shoal, with 10-15 cm of water. Further shocking produced no additional animals; however, this specimen extends the known range of *L. aepyptera* into the Rock Creek drainage of the lower Springs River. These recent records confirm Pflieger's (1975) assumption that additional collecting efforts would reveal a more extensive range than has been previously reported for the species. The record brings to 19 the total number of specimens located by the authors.

All known records of *L. aepyptera* in Arkansas are within a six-county area. Of the 19 located specimens, 15 (78.95%), were taken in Fulton, Izard and Sharp counties. At the present time, 12 watershed projects are in some stage of planning or operations within this six-county area (Ozark Foothills RC&D Council, 1977).

Watershed lakes are indicated as primary drainage solution measures in these project areas. Varying degrees of channelization, and resulting instream flow increases, are often incorporated in watershed projects (Funk, 1973), and result in decreased species diversity, reduced nesting areas and simplified food webs (Mauney and Harp, 1979).

Seversmith (1953) and Pflieger (1975) reported that during their development, ammocoetes of *L. aepyptera* were found in different environments within east coast and Missouri drainages, respectively. In each case, the larval period indicated was three years, and in each case, debris and sediment accumulations protected from the full force of stream flow were preferred larval habitat, especially in late winter and early spring. These areas would be particularly endangered during progressions on the existing watershed plan.

Robison (1974) referred to species whose "continual survival is unlikely without the implementation of protected measures" as endangered. Considering the larval habitat degradation accompanying progress on planned watershed measures, endangered status is considered warranted for the least brook lamprey should watershed activities resume within its range.

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ADDENDA

Since this manuscript went to press we have acquired additional information concerning *Lampetra aepyptera* in Arkansas. Thirteen *L. aepyptera* were collected with a standard dip net in isolated pools of North and South Sylamore Creeks in Stone County, Arkansas, on 30 March 1980 (Mike Wooten, *pers. comm.*). Specimens are deposited in the North Texas State University Fish Collection (NTSU MDZ#601-613). These additional specimens brings to 32, the total number of *L. aepyptera* located by the authors.

We thank Mr. Mike Wooten, Department of Biological Sciences, North Texas State University, Denton, Texas, for providing the additional information.

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IMMUNE RESPONSES OF RATS TO ANTIGENS OF MOLONEY LEUKEMIA VIRUS

Rats represent an attractive model for immunogenetic studies, since their major histocompatibility locus (RT1) resembles in structure the major histocompatibility locus of humans (HLA) (Gill, 1978), and since the immune responses to retroviruses that are associated with disease processes in humans resemble more closely the responses seen in rats than those seen in mice (Panem and Reynolds, 1979; Jones et al., 1978).

Brown Norway (BN) rats exhibit high antibody responses and high susceptibility to tumor induction by Moloney sarcoma virus, whereas Lewis (LEW) rats exhibit low responses and low susceptibility (Veit et al., 1977). In previous studies, control of these responses was shown to be influenced by genes linked to RT1, but an influence of other genes was also indicated (Jones et al., 1978; Veit et al., 1977). The present studies provide additional evidence that genes linked to RT1, if necessary, are not sufficient for high antibody responses when this locus is bred onto the background of a low responder strain.

The rat strains used in these studies, the sources and some of their properties are summarized in Table 1. Additional details of most strains were described by Festing and Staats (1973). Approximately equal numbers of males and females were used at three to six months of age.

Purified Moloney leukemia virus (MuLV) was obtained from the Resources Branch of the National Cancer Institute. A vaccine was prepared by treating the virus with 1:2000 formalin for 24 hrs at 4°C. Rats were immunized with vaccine by two subcutaneous and one intravenous injection at weekly intervals, and serum samples were collected one week after the last injection. Rat Moloney sarcoma tumor cells (MST) have been previously described (Jones et al., 1974). Rats were injected subcutaneously with 5×10^6 MST cells, and serum samples were collected 22 days later.

The p15, p30 and gp70 polypeptides of MuLV were prepared and labeled with ^{125}I as described (Jones et al., 1978), and radioimmunoassays for antibody conducted as described (Jones et al., 1977). Briefly, 0.3 to 0.5 ng ^{125}I labeled antigen was incubated with 5µl rat serum, and rat immunoglobulin with bound antigen was precipitated with an excess of goat anti-rat gamma globulin. Values were corrected for specificity by tests with normal rat serum from the strain being tested.

Table 2 shows that when immunized with oncogenic virus (MuLV) or with tumor cells (MST), BN rats exhibit high antibody responses and LEW low responses. LEW-1n congenics with RT1n of BN bred on a LEW background exhibited responses similar to LEW. TO rats, which differ genetically from all of the other three strains, exhibited responses similar to BN to p30 and responses lower than BN to gp70. This shows that higher responders to p30 are not automatically higher responders to other viral polypeptides. Table 3 shows that the phenomenon observed with LEW low responses. LEW-1n congenics with RT1n of BN bred on a LEW background exhibited responses similar to LEW. To rats, which differ congenics carrying the RT1f of AS2 on a LEW background were low or non-responders to p15. LEW-1f were also low responders to gp70 when immunized with MuLV (% precipitation 3.8 ± 2.6), and LEW rats were low responders to p15, p30 and gp70 in all tests when immunized with MuLV.

The responses of BN and LEW rats to several antigens have been compared (Gunther, 1978), and in most cases LEW are high responders and BN are low responders. Responses to MuLV are an exception, since BN are high and LEW are low. The results with LEW-1n show that such responses are influenced by genes that are not linked to the major histocompatibility locus of rats, RT1. Although immune responses of several animal species including humans are controlled by immune response (Ir) genes linked to the major histocompatibility locus (Benacerraf and McDevitt, 1972), the present report and other studies (Doig and Chesebro, 1979) demonstrate that other genetic loci are important. While it is clear that the major histocompatibility loci (H-2, RT1, HLA) are significant, we must not become overly fascinated by these genetic regions to the extent that we tend to ingore other genetic influences which are equally significant in immune responses and in disease susceptibility. The so-called "major influences" have been explored primarily because they are the easiest to measure, but the so-called "minor influences" should also be examined.

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Table 1. Properties of inbred and congenic rat strains.

Strain	RT1[b]	Source[c]	Responder Status[d]	Tumor Susceptibility[e]
Lewis (LEW)	l	UA	Low	Res
Brown Norway (BN)	n	UA	High	Sus
Tokyo (TO)	t	HU	Med	Res
AS2 (AS2)	f	MP	Med	N.D.
LEW-RT1n(BN) (LEW-1n)[a]	n	MP	Low	Res
LEW-RT1f(AS2) (LEW-1f)[a]	f	MP	Low	N.D.

[a]Congenics: LEW-1n, RT1n of BN bred onto LEW background; LEW-1f, RT1f of AS2 bred into LEW background.

[b]Allele of rat major histocompatibility locus.

[c]Sources: UA, University Arkansas Medical Sciences, Little Rock; HU, Hokkaido University, Sapporo, Japan; MP, Max-Planck Institute, Freiburg, West Germany.

[d]Antibody responses to MuLV antigens: High, high responders to all viral polypeptides; Low, low responders to all viral polypeptides; Med, high responses to some polypeptides but low responses to others.

[e]Susceptibility to tumor growth when inoculated with sarcoma virus or MST tumor cells: Res, resistant; Sus, susceptible; N.D., not determined.

Table 2. Antibody responses of rats to antigens of MuLV.[a].

Strain	RT1	Response to:[b] MuLV vaccine (p30)	MST cells (gp70)
LEW	l	4.4 ± 0.8	29.4 ± 8.0
BN	n	37.8 ± 12.2	70.3 ± 3.1
LEW-1n	n	5.5 ± 1.3	43.2 ± 6.9
TO	t	24.4 ± 7.9	41.5 ± 7.3

Percent of input (0.3-0.5 ng) ^{125}I-p30 precipitated by 5 μl serum, average of five animals ± std error.
[b]Each group was immunized with three injections of 100 μg MuLV and bled seven days after the last injection, or with one injection of 5×10^6 viable MST cells and bled 22 days later.

Table 3. Antibody responses of AS2 and LEW-1f rats to antigens of MuLV.[a]

Strain	RT1	Antigen and % precipitation:[b] p30	p15
AS2	f	0.9 ± 0.5	26.4 ± 8.1
LEW-1f	f	7.2 ± 2.4	1.5 ± 1.5

[a]Each animal received three injections of 100 μg MuLV.
[b]Percent of input (0.3-0.5 ng) ^{125}I-p15 or ^{125}I-p30 precipitated by 5 μl serum, average of five animals ± std error.

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FLEMING, T. H. 1969. Population ecology of three species of Neotropical rodents. Unpublished Ph.D. dissertation, Univ. Michigan, Ann Arbor, 231 pp.

JONES, I. C. 1957. The adrenal cortex. Cambridge Univ. Press, London 316 pp.

WRIGHT, P. L. 1966. Observations on the reproductive cycle of the American badger *(Taxidea taxus)*. Pp. 27-45, *In* Comparative biology of reproduction in mammals (I. W. Rowlands, ed.) Academic Press, London, xxi + 559 pp.

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