1978

Proceedings of the Arkansas Academy of Science - Volume 32 1978

Academy Editors

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VOLUME XXXII
1978

ARKANSAS ACADEMY OF SCIENCE
UNIVERSITY OF ARKANSAS BOX 2407
FAYETTEVILLE, ARKANSAS 72701

SPECIAL 4th CLASS

Arkansas Academy of Science, University of Arkansas Box 2407
Fayetteville, Arkansas 72701

PAST PRESIDENT OF THE ARKANSAS ACADEMY OF SCIENCE

Charles Brookover, 1917
Dwight M. Moore, 1932-33, 64
Flora Haas, 1934
H. H. Hyman, 1935
L. B. Ham, 1936
W. C. Munn, 1937
M. J. McHenry, 1938
T. L. Smith, 1939
P. G. Horton, 1940
I. A. 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

INSTITUTIONAL MEMBERS

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

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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
WESTARK COMMUNITY COLLEGE, Fort Smith

EDITORIAL STAFF

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ARKANSAS ACADEMY OF SCIENCE

Volume XXXII 1978

Proceedings

Secretary's Report

MINUTES OF THE SIXTY-SECOND ANNUAL MEETING—31 March - 1 April 1978

FIRST BUSINESS MEETING

Dr. Joe Nix, President, opened the meeting with a welcome to the members. He thanked Dr. P. M. Johnston, Local Arrangements Committee Chairman, and his committee for their efforts.

President Nix recognized Dr. John Gilmour for the Secretary's report. Gilmour reported that the Proceedings of the 61st Annual Meeting containing minutes of the First and Second Business Meetings were available. He said a motion for approval of the minutes would be made at the Second Business Meeting.

President Nix then recognized Dr. William L. 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 23, 1978

Cash Balance in Checking Account, April 1, 1977		$1,661.02
Reserve Funds, Savings Certificate		1,147.66
Reserve Funds, Passbook Account		2,871.41
Total Funds, April 1, 1977		$5,680.09

Income (April 1, 1977 through March 23, 1978)

1. Memberships		$1,788.00
a. Sustaining	$ 400.00	
b. Regular	1,240.00	
c. Associate	148.00	
2. Institutional Dues		450.00
3. Subscriptions to the PROCEEDINGS		771.00
4. Page Charges for the PROCEEDINGS		674.82
5. Registration Fees, ATU Meeting		214.00
6. Banquet Fees, ATU Meeting		508.00
7. Non-receipted Funds, ATU Meeting		200.75
8. Reimbursement for BIOTA Printing		10.00
9. Repayment on Returned Check		16.00
10. Interest on Reserve Funds		168.55
a. Certificate (6.5%)	57.33	
b. Passbook (5.25%)	111.22	
Total Income		$4,801.12

Disbursements (April 1, 1977 through March 23, 1978)

1. Meeting Expenses		1,084.95
a. Jim Hall, Ticket Refund (414)	8.00	
b. UA, Printing (416)	48.65	
c. Saga Food Svs, Banquet (421)	799.00	
d. UA, Printing BIOTA (427)	44.50	
e. Saga Food Svs, Coffee (429)	75.00	
f. Postmaster, Envelopes (444)	69.20	
g. Kwik Kopy, Printing (445)	20.60	
h. UA, Printing (451)	20.00	
2. Operating Expenses		121.69
a. Assoc, Acad. Sci., Dues (415)	10.00	
b. Postmaster, Postage (417)	6.50	
c. Returned Check	13.00	
d. Carson, Typing (423)	2.00	
e. Postmaster, Stamps (425)	15.60	
f. UA, Office Supplies (426)	5.41	
g. Postmaster, Box Rent (428)	4.00	
h. Postmaster, Box Rent (432)	6.00	
i. Letter Perfect, Typing (434)	18.00	
j. Postmaster, Box Rent (441)	6.00	
k. Postmaster, Postage (443)	19.50	
l. Fields, Typing (447)	7.50	
m. UA, Supplies (452)	8.18	
3. Awards		195.00
a. Berry, Sci. Talent (411)	20.00	
b. Chatrathi, Sci. Talent (412)	15.00	
c. Smith, Sci. Talent (413)	10.00	
d. Sci. Fair Assn., Support (419)	100.00	
e. Collegiate Acad., Support (436)	50.00	
4. Publication of the PROCEEDINGS		3,850.77
a. Wickliff, Expenses (420)	70.08	
b. UALR, Editorial Supplies (422)	4.75	
c. Phillips Litho, Printing (424)	3,245.99	
d. Gilmour, Postage (430)	12.93	
e. Edit. Asst., Salary (433)	28.70	
f. Edit. Asst., Salary (435)	47.50	
g. Heidt, Travel (437)	101.90	
h. Dept. Fin. & Admin., WH Tax (442)	2.60	
i. Edit. Asst., Salary (446)	158.40	
j. Heidt, Reimbursement (448)	3.37	
k. Watson, Phone Calls (449)	6.75	
l. Air-Land Agency, Travel (450)	57.00	
m. Edit. Asst., Salary (453)	110.80	
5. Publication of the NEWSLETTER		68.14
a. Bus Station, Shipping (438)	3.20	
b. Robison, Postage (439)	28.00	
c. UA, Printing (440)	36.94	
Total Disbursements		$5,320.55

SUMMARY

Beginning Balance, Checking and Reserve	$5,680.09
Plus Income	+4,801.12
Less Disbursements	-5,320.55
Total Funds on Hand, March 23, 1978	$5,160.66

****

Balance, Checking Account, McIlroy Bank 3/23/78	$1,090.59
Less Outstanding Checks (449,453)	117.55
Unobligated Funds in Checking Account 3/23/78	$ 973.04
FSLA Certificate Acct. 71-950 (12/31/77)*	1,204.99
FSLA Passbook Acct. 7679 (12/31/77)*	2,982.63
Total Funds Available 9/23/78	$5,160.66

*Next Interest Date 3/31/78 (Not included)

Note: The academy has an outstanding obligation for printing the PROCEEDINGS, Vol. 31 for $4,257.45. (Invoice No. 12936, Phillips Litho Co., Inc., 3/29/78.) This invoice covers the PROCEEDINGS that is being distributed at the University of Arkansas, Fayetteville Meeting.

Respectfully submitted,

William L. Evans
Treasurer

Evans said he would make a motion for approval of the financial statement at the Second Business Meeting.

President Nix recognized Dr. Leo Paulissen for a report on the Westinghouse Science Talent Search. Paulissen noted that Arkansas had 2 winners with 1 receiving an honorable mention at the national level.

President Nix stated Dr. Gary Heidt would give the Editor's report at the Second Business Meeting prior to recognizing Dr. Tom Palko, Director of the Junior Sciences and Humanities Symposium. Palko reported an excellent representation this year. He gave a brief summary of the program for the past meeting.

President Nix then recognized Dr. Carl Rutledge, President of the Arkansas Science Fair Association. Rutledge reported that the Science Fair and Junior Academy would meet jointly in 1978. He also stated that the financial condition of the Science Fair had improved and then made the following motion.

> I move that the Arkansas Academy of Science contribute $100 to the Science Fair Association for 1978.

The motion was seconded and passed.

President Nix then appointed the following committees: Auditing (M. L. Lawson, C. W. McCarty), Resolutions (J. M. Guenter, W. C. Guest), Meeting Place (C. Rutledge, G. E. Good, J. E. Moore).

President Nix asked for old business. Dr. Paulissen announced that the Biota Survey was continuing and that copies were available.

President Nix then called for new business. He stated that the Executive Committee had met and adopted a position statement regarding the relationship between the Senior Academy and organizations sponsored by the Senior Academy. The position statement is shown below.

> The Arkansas Academy of Science sponsors several organizations and programs which have been deemed appropriate by its membership. These organizations and programs include but are not limited to the Junior Academy of Science, the Collegiate Academy of Science, the Junior Science and Humanities Symposium, and the State Science Fair. The role of the Arkansas Academy of Science in sponsoring these respective functions is to encourage their development and in some cases provide financial assistance (with the approval of the Academy). Each of these organizations and programs functions independently under the leadership of a director and some type of governing board. It is understood that the director and the governing board will have the responsibility of the administration of the respective programs. The director of each program sponsored by the Academy is required to present a summary report to the membership at its annual meeting. The President of the Academy will appoint a person to serve as coordinator of all sponsored activities. This person will be responsible for providing coordination of scheduling of events and will serve as a liaison for these groups to the Executive Committee of the Academy.

President Nix then announced he had asked Dr. Wayne Everett to serve as coordinator and liason officer.

President Nix opened a discussion on a proposed change in Article IV (Officers) of the Constitution. He stated the proposed revision had been approved by the Executive Committee. Nix then read the proposed change which is shown below.

> The officers of the Academy shall be a President, a President-elect, a Secretary, a Treasurer, a Historian and an Editor who shall perform the duties usually pertaining to their respective offices. The Secretary, Treasurer, Historian, and Editor shall be chosen by ballot by the membership-at-large in an annual meeting and hold office for five years. The President-elect shall be chosen by ballot by the membership in the annual meeting and hold office for two years. The office of the President shall be filled by the preceeding year's President-elect. The term of the President shall be two years.
>
> The officers of the Academy, and the retiring President shall constitute the Executive Committee of the organization. If an officer is unable to complete his term, the President shall appoint a replacement to fill the unexpired term.

Much discussion followed.

President Nix adjourned the First Business Meeting.

SECOND BUSINESS MEETING

President Nix called the Second Business Meeting to order.

President Nix recognized Dr. John Gilmour who made the following motion.

> I move that the minutes of the 61st Annual Meeting published in the 31st Proceedings of the Arkansas Academy of Science be approved as written.

The motion was seconded and passed.

President Nix then recognized Dr. William Evans who made the following motion.

> I move the acceptance and approval of the Treasurer's financial statement and report for the period April 1, 1977, through March 23, 1978, as submitted to the membership and presented at the First Business Meeting.

The motion was seconded.

Dr. Clark McCarty then gave the report of the Auditing Committee shown below.

> The Auditing Committee has examined the financial statement and records of the Arkansas Academy of Science for the period April 1, 1977, through March 23, 1978, and find it complete and correct. We commend Dr. Evans, Treasurer, for an efficient and competent record for the Academy financial operations.

The motion by Evans was passed.

President Nix recognized Dr. Gary Heidt, Editor, who gave the report shown below.

> Thanks to Jim Wickliff in helping my transition as Editor and the Associate Editors for their professional handling of the manuscripts and programs for this year. The new Associate Editor for Biology is Dr. Dale Ferguson. My appreciation to section chairman for keeping sessions running smoothly and on time.
>
> This issue of the Proceedings, Vol. 31, represents the largest volume yet in the history of the AAS - 41 refereed articles and notes comprising 123 pages (54 manuscripts were submitted for publication). The journal is over 18% larger than last year and cost over $4500, including printing and editorial assistance. The average cost per book was $8.25, which means that we face severe cost problems.
>
> In an effort to keep costs down we have initiated a General Notes section in addition to feature articles. This has saved greatly in total pages. I have, perhaps made some mistakes in the assigning of manuscripts to these sections but this will improve in the future as authors submit their manuscripts to the appropriate section.
>
> In accordance with this, I have redone the Instructions to Authors and inserted a copy in each book. While too late for submitted manuscripts at this meeting all revisions and future manuscripts should adhere to these procedures and policies.
>
> At this point I would like to re-emphasize that we as faculty have a responsibility to our students to teach them scientific writing and if we are to encourage them in research and publi-

cation we have a duty to ensure that their manuscripts are quality material.

Those who wish can purchase Vol. 31 for $8.00, see John Gilmour.

As to other measures of cost control I would appreciate suggestions and comments, particularly on:

1. Total offset printing - perhaps needing 2 issues
2. Advertising
3. Limiting the size of journal
4. Page charges

Some hard decisions will need to be made in the near future.

Dr. Heidt then made the following motion.

I would like to move that the Academy allocate $400 for editorial assistance for preparing Volume XXXII (1978) of the Proceedings for publication during the next Academy fiscal year.

The motion was seconded and passed. A discussion of cost control measures followed. Dr. John Beadles suggested that a Friends of the Academy could be initiated for industrial supporters. Industry names could be printed in the Proceedings.

President Nix recognized Professor Robert Kirkwood, Historian. He requested everyone make history during the coming year.

President Nix then recognized Dr. Joe Guenter, Sponsor of the Collegiate Academy, who gave the following report.

Of the $175 granted by the Senior Academy $100 has been used to partially reimburse our luncheon speaker for travel and expenses. An additional $50 was requested for postage, mailing and partial expenses for the fall executive meeting in Little Rock. A balance of $37.40 remains in the collegiate treasury for the new president. This will help cover printing costs to replenish the supply of stationery and envelopes.

Guenter announced Rich Brown, OBU, would be next year's Collegiate Academy President. Dr. Glen Wood will be Sponsor, while Dr. Ed Wilson will be Co-Sponsor. William Casson, Past-President, announced Danna Rosell (Botany, 1st place), Gary Henson (Science Education, 2nd place); and Harral Burris, Betty Stallings, Freda Miller (honorable mention) as award winners.

Dr. Good then made the following motion.

I move that the Senior Academy approve up to $175 to cover expenses and operations of the Collegiate Academy for the coming year.

The motion was seconded and passed.

President Nix then called on Dr. Henry Robison, Editor of the Newsletter, who reported there will be a fall issue, but that the spring Newsletter will be discontinued. He then made the following motion.

I make a motion that $100 be set aside for the Arkansas Academy of Science Newsletter.

The motion was seconded and passed.

President Nix recognized Dr. James Friborough, AAAS Representative, who gave a brief report. Dr. Friborough pointed out that the Proceedings was well received at the last AAAS meeting.

President Nix then recognized Dr. Carl Rutledge for a report from the Meeting Place Committee. Dr. Rutledge recommended that Hendrix College be the site of the 1979 Annual Meeting. Dr. John Beadles then made the following motion.

I move that the invitation of Hendrix College to host the 1979 Arkansas Academy of Science be accepted and that Arkansas State University be considered for the 1980 meetings.

The motion was seconded and passed.

President Nix recognized Dr. Joe Guenter, Resolutions Committee, who read the following.

Be it Resolved:

By the members of the Academy in session on April 1 at the University of Arkansas in Fayetteville, that the Academy wishes to express its sincere thanks and appreciation to Dr. Charles Bishop, President of the University of Arkansas, the Arkansas Water Resources Research Center, University of Arkansas, and to the faculty and staff of the University of Arkansas, Fayetteville, for the use of their facilities and for their warm hospitality. The Academy gives special thanks to Dr. Bishop for his financial support.

Furthermore, the Academy extends its congratulations to the Local Arrangements Committee, Dr. P. M. Johnston, chairman, and to the chairpersons of the Academy sections; John Beadles, Robert Watson, Steven Day, Alex Nisbet, Neal Buffalo, John Pickett, Dale Ferguson, Timothy Klinger, Norman Williams, and Ronald Konig.

The Academy also wishes to express its thanks to Joe Nix, President of the Academy, John Gilmour, Secretary, William L. Evans, Treasurer, Gary Heidt, Editor, and Robert Kirkwood, Historian 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 oranizations 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; Joe Guenter, Sponsor, Collegiate Academy of Science; Carl Rutledge, Director, State Science Fair; and Leo Paulissen, Science Talent Search.

Dr. Guenter moved the resolutions be adopted. The motion was seconded and passed.

Dr. Beadles resolved that Dr. Heidt had done a fine job as Editor. The resolution passed.

President Nix then asked for old business.

President Nix asked Dr. Gilmour to read the proposed change in Article IV of the Constitution. After the reading, Gilmour moved adoption and Dr. Dwight Moore seconded. After much discussion, the motion failed (34 yes, 17 no).

President Nix then asked for new business and recognized Dr. Henry Robison for the Nominating Committee who made the following motion.

On behalf of the Nominating Committee, I would like to place the name of Leon Richards in nomination for the position of President-elect.

Dr. George Harp moved that Dr. Richards be elected by acclamation. The motion was seconded and passed.

President Nix then made his farewell statement. He said he looked at his year as a learning experience and appealed to the Academy to explore areas where the scientific community needs to be heard. President Nix then passed the gavel to Dr. P. M. Johnston, President-Elect.

President Johnston then appointed a Nominating Committee consisting of Clarence Sinclair, Earl Hannebrink and David Becker. He also acknowledged the assistance of the Secretary, Treasurer and Dr. E. E. Dale in the preparation for the Annual Meeting.

President Johnston adjourned the Second Business Meeting.

Respectfully submitted,

John T. Gilmour, Secretary

PROGRAM
Arkansas Academy of Science

Sixty-Second Annual Meeting

UNIVERSITY OF ARKANSAS AT FAYETTEVILLE
Fayetteville, Arkansas

Meeting concurrently with sessions of:

The Collegiate Academy of Science
The Junior Academy of Science

Friday, 31 March

SENIOR, COLLEGIATE, JUNIOR ACADEMIES -- Registration

SENIOR ACADEMY -- Executive Board Meeting

COLLEGIATE BUSINESS MEETING I

SENIOR ACADEMY -- First General Business Meeting

JUNIOR ACADEMY -- Westinghouse Talent Search Paper Presentations

Lunch

SENIOR, COLLEGIATE, JUNIOR ACADEMIES -- Registration

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

Chemistry
Mathematics and Physics
General Physiology/Invertebrate Zoology
Environmental and Engineering Sciences I
Science Education

JUNIOR ACADEMY -- Papers [Biological and Physical Sciences, Concurrent Sessions]

JUNIOR ACADEMY -- Executive Meeting

SENIOR, COLLEGIATE, JUNIOR ACADEMIES -- Banquet

RESERVOIR SYMPOSIUM -- Sponsored by Water Resources Research Center, University of Arkansas

Saturday, 1 April

SENIOR, COLLEGIATE, JUNIOR ACADEMIES -- Registration

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

Vertebrate Zoology
Botany
Environmental and Engineering Sciences II
Anthropology/Sociology
Geology

JUNIOR ACADEMY -- Business Meeting

JUNIOR ACADEMY -- Awards Presentation

SENIOR, COLLEGIATE ACADEMIES -- Second General Business Meeting

SECTION PROGRAMS

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

CHEMISTRY SECTION
Chairman: Alex R. Nisbet

*EFFECT OF MODIFICATION OF LYSINE 88 ON CYTOCHROME C REACTIVITY.
Freda Miller, University of Arkansas at Fayetteville

DEMONSTRATIONS AND DISCUSSIONS OF USES AND EFFECTS OF CALCULATORS AND COMPUTERS IN THE TEACHING OF CHEMISTRY. Room 115 of the Chemistry Building

MATHEMATICS AND PHYSICS SECTION

*TEMPORAL PULSE CONTROL OF A MODELOCKED LASER.
James A. Berry, Mark A. Newbold and G. J. Salmo, University of Arkansas at Fayetteville

*LOIS: A LASER OPERATED ION SOURCE.
M. R. Carruth, R. H. Hughes, R. J. Anderson and L. Gray, University of Arkansas at Fayetteville

*THE DESIGN AND CONSTRUCTION OF AN INEXPENSIVE ANECHOIC CHAMBER FOR MEASUREMENT OF ACOUSTICAL RADIATION.
Charles Hughes, University of Central Arkansas

*STANDARD VUV RADIATION FROM ELECTRON IMPACT ON METALS.
Tim Heumier and R. H. Hughes, University of Arkansas at Fay-Fayetteville

*ELECTRON IMPACT EXCITATION OF TRIPLET STATES OF H_2.
R. J. Anderson and R. L. Day, University of Arkansas at Fayetteville, and F. A. Sharpton, Northwest Nazarene College

*THE PROJECTION BLINKING COMPARITOR 'PROBLICOM'.
Maurice L. Ayers, University of Central Arkansas

*THE TEMPERATURE DEPENDENCE OF THE ELASTIC MODULI OF A MACHINABLE GLASS-CERAMIC.
J. A. Brewer, S. N. Harrington and D. O. Pederson, University of Arkansas at Fayetteville

GENERAL PHYSIOLOGY/INVERTEBRATE ZOOLOGY SECTION
Chairman: Robert L. Watson

SPIDERS IN THE UNIVERSITY OF ARKANSAS ENTOMOLOGY MUSEUM.
John S. Heiss and E. Phil Rouse, University of Arkansas at Fayetteville

A PRELIMINARY REPORT OF THE NEPIDAE (HEMIPTERA) IN ARKANSAS.
George L. Harp, Arkansas State University

A CHECKLIST OF ARKANSAS ARCHTIIDAE.
Sheila M. Hoelscher and E. Phil Rouse, University of Arkansas at Fayetteville

THE BLIND BEETLE FAUNA OF ARKANSAS: COMPOSITION, DISTRIBUTION, ORIGIN. (COLEOPTERA: CARABIDAE; LEPTINIDAE; PSELAPHIDAE)
Robert T. Allen, University of Arkansas at Fayetteville

EFFECTS OF SIMULATED HIGH ALTITUDE. I. METHEMOGLOBULIN, OXYGEN-HEMOGLOBIN DISSOCIATION AND SURVIVAL.
C. P. Olander, J. L. Thomas, J. S. Sharp, and D. E. McKay, Arkansas State University and Austin College

EFFECTS OF SIMULATED HIGH ALTITUDE. II. METHEMOGLOBIN, 2,3-DIPHOSPHOGLYCERATE AND METHEMOGLOBIN REDUCTION.
W. J. Waldrip and C. P. Olander, Arkansas State University

EFFECTS OF HYPOBARIC HYPOXIA ON SOME ENZYME SYSTEMS IN THE MAMMALIAN LIVER.
D. A. Baeyens and M. J. Meier, University of Arkansas at Little Rock

A COMPARISON OF UREA TOLERANCES OF LACTATE DEHYDROGENASE FROM SIX ELASMOBRACH AND ONE MAMMALIAN SPECIES.
C. E. Parr, University of Arkansas at Fayetteville

ULTRAVIOLET LIGHT REACTIVATION OF GAMMA RAY-INDUCED LETHAL DAMAGE IN VERTEBRATE CELLS.
Stewart W. Cross and J. Gaston Griggs, John Brown University

EFFECT OF SANGUINARINE, AN EXTRACT OF *SANGUINARIA CANADENSIS*, ON FROG SKIN POTENTIAL DIFFERENCE AND SHORT CIRCUIT CURRENT.
James R. Nichols, K. D. Straub, and S. Abernathy, University of Central Arkansas, VA Hospital, Little Rock, and Duke University

THE INFLUENCE OF LEAD, AN ENVIRONMENTAL POLLUTANT, ON METAMORPHOSIS OF *RANA UTRICULARIA*.
Gloria Yeung, University of Arkansas at Fayetteville

ENVIRONMENTAL SCIENCE AND ENGINEERING SCIENCES I SECTION
Chairman: John K. Beadles

THE CONCENTRATION OF RADIONUCLIDES IN DARDENELLE LAKE (ADDENDUM).
D. M. Chittenden, II and Larry McFadden, Arkansas State University

MOVEMENTS OF CHANNEL AND FLATHEAD CATFISH IN BEAVER RESERVOIR IN NORTHWEST ARKANSAS.
Thomas O. Duncan and Milton R. Myers, Jr., U.S. Fish and Wildlife Service

ADDITIONS TO THE FISH FAUNA OF PINEY CREEK, IZARD COUNTY, ARKANSAS.
William J. Mathews and Robert S. Mathews, Roanoke College and Arkansas State University

GROWTH OF CARP *(CYPRINUS CARPIO)* FROM BEAVER RESERVOIR.
Raj V. Kilambi and Walter Robinson, University of Arkansas at Fayetteville

FISHES OF THE MOUNTAIN PROVINCE SECTION OF THE OUACHITA RIVER.
John L. Harris and Neil H. Douglas, University of Tennessee at Knoxville and Northeast Louisiana University

FISHES OF THE CADDO RIVER, ARKANSAS, AFTER IMPOUNDMENT OF DE GRAY LAKE.
Michael R. Dewey and Thomas E. Moen, U. S. Fish and Wildlife Service

DISTRIBUTION AND HABITAT OF THE TAILLIGHT SHINER, *NOTROPIS MACULATUS* (HAY), IN ARKANSAS.
Henry W. Robison, Southern Arkansas University

BREEDING ASPECTS OF THE CREOLE DARTER, *ETHEOSTOMA COLLETTEI*, IN THE UPPER SALINE RIVER, SALINE COUNTY, ARKANSAS.
Mike R. Galster and John D. Rickett, University of Arkansas at Little Rock

LOSS OF LARVAL FISH BY EPILIMINIAL DISCHARGE FROM DE GRAY LAKE, ARKANSAS.
Thomas E. Moen and Michael R. Dewey, U. S. Fish and Wildlife Service

THE FISHES OF MORO CREEK, A LOWER OUACHITA RIVER TRIBUTARY, IN SOUTHERN ARKANSAS.
Stephen A. Winters and Henry W. Robison, Southern Arkansas University

THE INFLUENCE OF AMMONIA ON AEROMONAD SUSCEPTIBILITY IN CHANNEL CATFISH *ICTALURUS PUNCTATUS*, RAFINESQUE.
R. M. Flagg and L. W. Hinck, Arkansas State University

LONGEVITY OF WHITE BASS IN BEAVER RESERVOIR, ARKANSAS.
T. O. Duncan and Milton R. Myers, Jr., U. S. Fish and Wildlife Service

SCIENCE EDUCATION SECTION
Chairman: Neal Buffaloe

PHYSICS AND HUMAN AFFAIRS: A RELEVANT SCIENCE COURSE FOR NON-SCIENTISTS.
Art Hobson, University of Arkansas at Fayetteville

*A SCIENCE WORKSHOP FOR HIGH SCHOOL STUDENTS.
Gary D. Henson, University of Central Arkansas

VERTEBRATE ZOOLOGY SECTION
Chairman: John D. Rickett

THE PRESENCE OF AN UNUSUAL EOSINOPHILIC STAINING SUBSTANCE IN THE BLOOD OF SNAKES.
James J. Daley and Charles H. Calhoun, University of Arkansas for Medical Sciences and the Little Rock Zoological Gardens

SOME PHYSIOLOGICAL AND MORPHOLOGICAL ADAPTATIONS FOR UNDERWATER SURVIVAL IN *NATRIX RHOMBIFERA* AND *ELAPHE OBSOLETA*.
Chris T. McAllister, D. A. Baeyens and L. F. Morgans, University of Arkansas at Little Rock

A REQUEST FOR INFORMATION ON THE RED-COCKADED WOODPECKER *(PICOIDES BOREALIS)* IN ARKANSAS.
Fred L. Burnside, University of Arkansas at Fayetteville

SPECIES COMPOSITION AND DIVERSITY OF HAWK POPULATIONS IN NORTHEASTERN ARKANSAS.
Earl L. Hanebrink, Alan F. Posey, and Keith Sutton, Arkansas State University

PATTERNS OF AUTUMN SWARMING ACTIVITY OF EIGHT SPECIES OF BATS AT THE ENTRANCE OF AN OZARK CAVE.
David A. Saugey, Arkansas State University

DISTRIBUTION OF BATS IN THE DELTA REGION OF NORTHEAST ARKANSAS.
James E. Gardner, Arkansas State University

AN UNUSUAL SPECIES ASSOCIATION FROM A BAT GRAVEYARD IN AN OZARK CAVE.
D. A. Saugey, R. H. Baber, and V. R. McDaniel, U. S. Forest Service, Little Rock Museum of Science and History, and Arkansas State University

STATUS OF THE ENDANGERED WESTERN BIG-EARED BAT *PLECOTUS TOWNSENDII INGENS)* IN ARKANSAS.
Michael J. Harvey, V. Rick McDaniel, and Michael L. Kennedy, Memphis State University and Arkansas State University

PRE- and POSTNATAL GROWTH AND DEVELOPMENT OF *MYOTIS GRICESCENS* IN NORTHCENTRAL ARKANSAS.
D. A. Saugey, Arkansas State University

RANGES AND STATUS OF THE NUTRIA *(MYOCASTOR COYPUS)* IN ARKANSAS.
Joe W. Bailey and Gary A. Heidt, University of Arkansas at Little Rock

A SUMMARY OF THE STATUS OF HARVEST MICE *(REITHRODONTOMYS)* IN ARKANSAS.
John C. Huggins and V. Rick McDaniel, Arkansas State University

INTRASPECIFIC VARIATION IN THE PRAIRIE VOLE, *MICROTUS OCHROGASTER*.
James C. Huggins and Michael L. Kennedy, Memphis State University

TASTE MASKING: A FUNCTION OF EXAGGERATED PRANDIAL DRINKING IN DESALIVATE MICE.
Richard C. Lewis, University of Arkansas at Little Rock

BOTANY SECTION
Chairman: Dale V. Ferguson

*THE INHIBITORY ACTIVITIES OF COLICINOGENIC STRAINS OF *ESCHERICHIA COLI*.
Benny Green and Leo Paulissen, University of Arkansas at Fayetteville

*SOME ULTRASTRUCTURAL OBSERVATIONS OF THE GELATINOUS MATRIX OF THE UNICELLULAR GREEN ALGA, *HAEMATOCCUS*.
Danna Rosell and Harral Burris, University of Arkansas at Little Rock

*SOME ELECTRON MICROSCOPICAL OBSERVATIONS ON GREEN AND APPARENT ALBINO SEEDLINGS OF THE TRIFOLIATE ORANGE, *PONCIRUS TRIFOLIATA*.
Betty Stallings, University of Arkansas at Little Rock

*EFFECT OF LIMESTONE ON SPRING WEED POPULATIONS IN A FERTILIZED COSTAL BERMUDAGRASS SOD.
H. C. Fulcher and L. F. Thompson, University of Arkansas at Fayetteville

*EFFECT OF FERMIX-ZINC SEED COATINGS ON GERMINATION AND EARLY GROWTH OF RICE PLANTS.
D. A. Famotemi and L. F. Thompson, University of Arkansas at Fayetteville

SOME LICHENS FROM THE ARCHEOLOGICAL SITES, SOMERSET ISLAND, NORTHWEST TERRITORIES, CANADA.
Nancy McCartney, University of Arkansas at Fayetteville

SCANNING ELECTRON MICROSCOPICAL OBSERVATIONS ON THE DEVELOPMENT OF CORK WINGS IN *EUMONYMUS ALATUS*.
William Bowen and Danny Lieblong, University of Arkansas at Little Rock

SCALED CHRYSOPHYSCEAE OF ARKANSAS. II.
Robert A. Andersen, University of Arkansas at Fayetteville

LIGHT INDUCED ATYPICAL ENLARGEMENT OF MAIZE MESOCOTYLS.
Pamela J. Camp and James L. Wickliff, University of Arkansas at Fayetteville

THE COMPOSITION AND ABUNDANCE OF VEGETATION IN THE WATER-LEVEL FLUCTUATION ZONES OF THREE OZARK LAKES.
James R. Sullivan, Jr., University of Arkansas at Fayetteville

THE EFFECTS OF THE McCLELLAN-KERR NAVIGATION PROJECT ON VEGETATION COMMUNITIES OF THE ARKANSAS RIVER.
Edward E. Dale, Jr., University of Arkansas at Fayetteville

MONARDA STIPITATOGLANDULOSA IN ARKANSAS.
Gwen Barber, University of Arkansas at Fayetteville

THE VASCULAR PLANTS OF MISSISSIPPI COUNTY, ARKANSAS.
Edward L. Richards and Thad Wyatt, Arkansas State University

AN ATLAS AND ANNOTATED LIST OF THE VASCULAR PLANTS OF ARKANSAS.
Edwin B. Smith, University of Arkansas at Fayetteville

RELATIVE DOMINANCE AND DISTRIBUTIONAL PATTERNS OF DIATOM SPECIES IN THE BUFFALO RIVER, ARKANSAS.
Neil Woomer and Richard L. Meyer, University of Arkansas at Fayetteville

ENVIRONMENTAL AND ENGINEERING SCIENCES II SECTION
Chairman: John K. Beadles

CHANGES IN SPECIES COMPOSITION AND ABUNDANCE OF FISHES IN BEAVER RESERVOIR LAKE FOR THE FIRST 15 YEARS OF IMPOUNDMENT.
William C. Rainwater, U. S. Fish and Wildlife Service

*AN AIR MONITORING PROGRAM IN BENTON COUNTY, ARKANSAS.
C. B. Richardson, M. A. Newbold, and J. W. Moore, University of Arkansas at Fayetteville

RENOVATION OF NITROGENOUS WASTEWATER VIA LAND APPLICATION.
J. T. Gilmour, A. C. Peer and D. C. Regan, University of Arkansas at Fayetteville

PRIMARY PRODUCTIVITY, WATER QUALITY, AND LIMITING FACTORS IN LAKE CHICOT.
Edmond J. Bacon, University of Arkansas at Monticello

ANTHROPOLOGY/SOCIOLOGY SECTION
Chairman: Timothy C. Klinger

EFFECTS OF THULE ESKIMOS ON SOILS AND VEGETATION AT SILUMIUT, NORTHWEST TERRITORIES, CANADA.
Nancy G. McCartney, University of Arkansas at Fayetteville

FRESHWATER BIVALVE SHELLS AS INDICATORS OF PREHISTORIC SEASONALITY: EXPERIMENTAL RESULTS.
Robert H. Ray, University of Arkansas at Fayetteville

ALPHA-RECOIL TRACK DATING OF ARCHEOLOGICAL CERAMICS.
Daniel Wolfman and Thomas M. Rolniak, Arkansas Tech University and the University of Arkansas at Fayetteville

EXPERIMENTAL MODIFICATIONS OF THE THIN-SECTION TECHNIQUE UTILIZING ARCHAEOLOGICAL BONE.
Jay Sperber, University of Arkansas at Fayetteville

METHODOLOGY FOR ANALYSIS OF DIET GRIT SIZE ON MOLAR ATTRITION FOR FOURCHE MALINE AND CADDO PEOPLE.
Judith C. Stewart, Mary Powell, and J. C. Rose, University of Arkansas at Fayetteville

ADDITIONAL MORTUARY INFORMATION FROM THE MILLERS CROSSING SITE, 3SVL0, SEVIER COUNTY, ARKANSAS.
Michael P. Hoffman, University of Arkansas at Fayetteville

FAMILY AND COMMUNITY ON THE NEW ENGLAND FRONTIER: FAMILY RECONSTRUCTION, SETTLEMENT PATTERN, AND "THE COMMUNITY AT PALMERS RIVER".
Leslie C. Abernathy III, University of Arkansas at Pine Bluff

SOCIOBIOLOGY AND ITS APPLICATION IN SOCIOLOGY.
Robert Bolin and Susan Bolton Bolin, Arkansas State University

REHABILITATION OF THE 'RUINED WOMAN': ZAPOTEC PEASANTS COPE WITH DEVIANCE.
Judith M. Brueske, University of Arkansas at Fayetteville

POWWOW ROOTS: THE GRASS DANCE/DREAM DANCE MOVEMENT.
Gloria A. Young, Indiana University

GEOLOGY SECTION
Co-Chairmen: Norman F. Williams and Ronald H. Konig

GEOCHEMISTRY OF A CARBONATITE IN MONTGOMERY COUNTY, ARKANSAS.
George H. Wagner and Ronald H. Konig, University of Arkansas at Fayetteville and Michael D. Jones, Lucky McUranium Corp.

PETROLOGY OF IGNEOUS AND METAMORPHIC XENOLITHS IN CARBONATITE INTRUSION, WEST CENTRAL ARKANSAS.
John R. Mitchell, University of Arkansas at Fayetteville

PETROLOGY OF THE HATTON TUFF (STANLEY GROUP, MISSISSIPPIAN), SOUTHWEST ARKANSAS AND SOUTHEAST OKLAHOMA.
James W. Langford, University of Arkansas at Fayetteville

LITHOSTRATIGRAPHY AND PETROGRAPHY OF THE CLIFTY FORMATION (MIDDLE DEVONIAN) AT ITS TYPE LOCALITY, BENTON COUNTY, ARKANSAS.
Marcus Borengasser, University of Arkansas at Fayetteville

STRUCTURAL GEOLOGY OF THE BRENTWOOD-ST. PAUL AREA, NORTHWEST ARKANSAS.
Mikel R. Shinn, University of Arkansas at Fayetteville

GEOMETRY AND DEPOSITIONAL SYSTEMS OF THE ORR AND PATTERSON SANDS, BLOYD FORMATION (PENNSYLVANIAN), EASTERN FRANKLIN AND WESTERN JOHNSON COUNTIES, ARKANSAS.
Michael E. Corbin, University of Arkansas at Fayetteville

DEPOSITIONAL SYSTEMS OF THE SELLS AND CECIL SANDSTONES, ATOKA FORMATION (PENNSYLVANIAN), EASTERN CRAWFORD AND WESTERN FRANKLIN COUNTIES, ARKANSAS.
Christopher A. Cardneaux, University of Arkansas at Fayetteville

GENESIS OF PLEISTOCENE CLAYS IN NORTHCENTRAL MISSOURI.
M. J. Guccione, University of Arkansas at Fayetteville

Arkansas Collegiate Academy of Science

William H. Casson	Bettina Casson	Teri Garner
President	Secretary	Treasurer

Sponsor: Mr. Joe Guenter
Co-Sponsor: Dr. Glen Good

MINUTES OF THE FIRST BUSINESS MEETING, 31 MARCH 1978

The first business meeting of the Arkansas Collegiate Academy of Science was called to order by the presiding president, William Casson. The minutes were read by the secretary, Bettina Casson. The minutes were approved. The financial report was submitted by Rich Brown, as the treasurer was unable to attend the meeting. The Collegiate account contained $37.50.

The following officers were elected for 1978-79:

President	-Rich Brown, Ouachita Baptist University
Secretary	-Sandra Thompson, Ouachita Baptist University
Treasurer	-David Dube, Ouachita Baptist University
Sponsor	-Mr. Glen Good, Ouachita Baptist University

At this meeting we had as our guest speaker Dr. Ronald Canterna of Louisiana State University, who presented a program on the origin of the Universe. The meeting was adjourned by the presiding president.

MINUTES OF THE SECOND BUSINESS MEETING, 1 APRIL 1978

The second business meeting of the Arkansas Collegiate Academy of Science was called to order by the presiding president, William Casson. A motion was made, seconded, and passed that Mr. Glen Good should request $175 from the Senior Academy.

The following officers were elected for 1978-79:

President-elect	-Frank Brown, Harding
Co-Sponsor	-Dr. Ed Wilson, Harding

The new president, Rich Brown, took charge of the meeting. A discussion of the previous day's activities followed. There was also a discussion concerning the planning of activities for the next Arkansas Collegiate Academy meeting.

The names of the winners for the paper presentation were announced at this meeting.

In the Biological Science section the first place certificate was awarded to Danna Rosell. In the Physical Science section, the first place certificate was awarded to Gary D. Henson. The following got an honorable mention: Harral Burris, Betty Stallings, and Freda Miller. The meeting was adjourned by the new president, Rich Brown.

Respectfully submitted,

Bettina Casson

Approved by Rich Brown

ABSTRACTS OF PAPERS PRESENTED BY COLLEGIATE ACADEMY MEMBERS

Editor's Note: Not included in the following abstracts are those of H. C. Fulcher and Charles Hughes, 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 *.

ELECTRON IMPACT EXCITATION OF TRIPLET STATES OF H_2.

R. J. Anderson and R. L. Day, Department of physics, University of Arkansas; F. A. Sharpton, Department of Physics, Northwest Nazarene College

The electron impact excitation of the H_2 triplet states $(1s\sigma)(np\pi)^3\pi_u$ $(n=3,4,5)$ is studied through observations of the radiative transitions $(1s\sigma)(np\pi)^3\pi_u \rightarrow (1s\sigma)(2p\pi)^3\Sigma_g^+$. Rotational lines corresponding to the $(v'=0\rightarrow v''=0)Q1$, $(v'=\rightarrow v''=1)Q1$, $(v'=2\rightarrow v''=2)Q1$ and $(v'=3\rightarrow v''=3)Q1$ transitions are isolated at a spectral resolution of $\Delta\lambda \leq 3$ Å FWHM and are studied using the optical method and delayed-coincidence techniques. Optical excitation functions are obtained for the electron energy range 0-500 eV at H_2 target gas pressure ≤ 50 mtorr. Intensity measurements of the rotational lines at 25 eV are characterized by a linear dependence upon H_2 gas pressure and are placed on an absolute scale by direct comparison with the $H\alpha$ and $H\beta$ spectral lines produced by dissociative excitation of H_2. Radiative lifetime measurements for the rotational transitions yield values in the range approximately 35 to 50 nanoseconds.

THE PROJECTION BLINKING COMPARITOR "PROBLICOM".

Maurice L. Ayers, Physics Department, University of Central Arkansas, Conway, Arkansas 72032

The function, design and construction of Mr. Ben Mayer's original comparitor (details published in "Sky and Telescope", January, 1976) are described. The instrument has been adopted into the University of Central Arkansas astronomy program. When properly used, this device enables one to confirm, or discover all or some of the following astronomical objects or events: variable stars, comets, asteroids, novaes, and supernovaes. The comparitor operation is demonstrated using transparancies made by astronomy students at U.C.A.

TEMPORAL PULSE CONTROL OF A MODELOCKED DYE LASER.

James A. Berry, Mark A. Newbold and G. J. Salamo, Dept. of Physics, University of AR, Fayetteville, AR 72701

The introduction of a time varying loss into an active laser cavity is known to produce a fixed phase relation between the oscillating modes in the laser cavity. While theories have been developed to explain the resulting locking process and predict temporal pulse lengths for any number of modes participating in the locking process, experiment has generally focused on the temporal pulse length resulting from a laser operating with only slight restriction to its bandwidth. Bandwidths of dye lasers operating in this manner are typically on the order of 100 GHz with mode spacing of about 0.1 GHz. Consequently, a large number of modes are generally oscillating. Few attempts have been made, however, to utilize the relation between bandwidth and pulse length for pulse length control. Our literature search reveals that no experiment resulting in pulse length control by control of mode number has been reported. The purpose of this research is to explore the possibility of pulse length control through control of the laser bandwidth by the use of inter-cavity Fabry-Perot etalons.

THE TEMPERATURE DEPENDENCE OF THE ELASTIC MODULI OF A MACHINABLE GLASS-CERAMIC.

J. A. Brewer, S. N. Harrington*, and D. O. Pederson, Physics Department, University of Arkansas, Fayetteville, AR 72701

The velocity of longitudinal and transverse ultrasound at a frequency of 10 MHz has been measured in a machinable ceramic (Code 9658, Macor, Glass-Ceramic Dept., Corning Glass Works, Corning, N.Y.). The glass-ceramic is a glassy matrix containing about 50% (volume) mica crystallites which are approximately 2μ thick and 5-10μ square. Measurements were made using a pulse-echo overlap technique from 4.2 to 300K. The elastic moduli calculated from the sound velocities are in general agreement with the technical values specified at room temperature for this material. The general temperature dependence of the elastic moduli is characteristic of a glassy material.

*Present Address: Rice University, Houston, TX 77001

SOME ELECTRON MICROSCOPICAL OBSERVATIONS OF THE CHLOROPLASTS OF UNICELLULAR GREEN ALGA, *EREMOSPHAERA VIRIDIS*.

Harral Burris and Danna Rosell, Dept. Biology, University of Arkansas at Little Rock, Little Rock, Arkansas 72204

The vegetative cells of *Eremosphaera viridis*, a fresh-water alga found in acidic habitats, are relatively large. Each cell is highly vacuolate and contains numerous chloroplasts. The chloroplasts possess a typical algal membrane system of elongated thylakoids and one or more pyrenoids. Transmission electron microscopical observations of the interrelationship between the thylakoids and the pyrenoid will be discussed.

LOIS: A LASER OPERATED ION SOURCE.

M. R. Carruth, R. H. Hughes, R. J. Anderson, and L. Gray, Physics Dept., University of Arkansas, Fayetteville, Ark. 72701

A novel, pulsed heavy-ion source is being developed at the University of Arkansas. Ions are extracted from the blowoff produced by focussing a 25 megawatt pulse of 1.06 micron radiation from Nd:yag Q-switched laser onto solid targets. Experiments are now being performed on commercially pure aluminum targets. Aluminum ions are stripped from the dense plasma plume at a gridded high potential extraction gap. A gridded Einzel lens is then used to focus the resulting space-charge-limited ion beam. Some preliminary results will be presented.

EFFECT OF FERMIX-ZINC SEED COATINGS ON GERMINATION AND EARLY GROWTH OF RICE PLANTS.

D. A. Famotemi and L. F. Thompson, University of Arkansas, Fayetteville

Zinc deficiency in rice (*Oryzae sativa* L.), a common problem in Arkansas' calcareous rice soils, can generally be controlled by the broadcast application of 10 kg/ha of Zn, as $ZnSO_4$, at planting time. In recent years there has been an interest in the rice plant's response to much smaller quantities of Zn coated directly onto the rice seed. Concomitant with the interest in Zn seed coatings, the question of the effect of seed coatings on germination and early plant growth has been raised. In this investigation the seed of three rice cultivars was coated with FERMIX-Zinc (a Zn lignosulfonate) at the rate of 7.3 kg/100 kg seed (1 kg Zn/100 kg seed). The seed was grown for 21 days, in a calcareous silt loam (pH 7.3) in the greenhouse. Daily counts on plant stands showed that plants from coated seed were almost a day slower in emerging than plants from uncoated seed, but by the 9th day counts from the treated and untreated seed were virtually the same.

By the 11th day more plants had emerged from the coated seed than from the uncoated seed. Data on plant height, dry weight yields, and the Zn content of the rice tissue, taken 21 days after planting, showed the Zn-coated seed to produce superior results.

A SCIENCE WORKSHOP FOR HIGH SCHOOL STUDENTS.

Gary D. Henson, Dept. Physics, University of Central Arkansas, Conway, Arkansas 72032

The planning, preparation, and staging of a High School Workshop in the fields of Physics, Chemistry, Biology, and Mathematics as done by the students representing each field at the University of Central Arkansas will be presented. A slide show of this year's Workshop will also be shown with the presentation.

Ed. Note: This paper won the annual Second Place award

STANDARD VUV RADIATION FROM ELECTRON IMPACT ON METALS.

Tim Heumier and R. H. Hughes, Dept. of Physics, University of Arkansas, Fayetteville, AR 72701

An optical standard in the vacuum ultraviolet is proposed, namely, the light emitted from fast (100 keV) electrons as they impact on metal surfaces. This standard would have the qualities desirable in a standard optical source: ease of handling, continuous spectrum of adequate intensity, isotropic angular distribution, stability and reproducibility, scalability, and being generated directly in the vacuum. A secondary standard using 10 keV electrons would have application in orbiting observatories and other space-related endeavors. Qualitative aspects of the theory are discussed and a description of the experimental apparatus is given.

EFFECT ON MODIFICATION OF LYSINE 88 ON CYTOCHROME C REACTIVITY.

Freda Miller, Dept. of Chemistry, The College of the Ozarks, Clarksville, Arkansas 72830 and F. S. Millett, Dept. of Chemistry, University of Arkansas, Fayetteville, Arkansas 72701

A sample of trifluoroacetylated lysine 88 cytochrome c was purified by means of ion-exchange chromatography. Assays were performed to observe the effect of modification of lysine 88 in cytochrome c on reactions with cytochrome c reductase and cytochrome oxidase.

The results of these assays indicated that lysine 88 is involved in the binding of the cytochrome c reductase and cytochrome oxidase. The question as to whether the binding site for cytochrome c reductase and cytochrome oxidase are one and the same or two separate sites is still under investigation.

THE INHIBITORY ACTIVITIES OF COLICINOGENIC STRAINS OF *ESCHERICHIA COLI*.

Leo Paulissen and Benny Green, Department of Botany and Bacteriology, University of Arkansas, Fayetteville, Arkansas 72701

Several strains of *Escherichia coli*, capable of producing an antibiotic-like substance called colicin, have been isolated. Colicins differ from classical antibiotics by their narrow spectrum of activity, their action on strains closely related to the colicin producer, and their chemical complexity.

Several of the isolated strains are active against notably pathogenic bacteria such as *Salmonella enteritidis* and *Shigella paradysenteriae*.

Colicinogenic strains can be established in the microflora of white mice by the oral route. The course of residency can be monitored by the sampling of mice feces for bacterial having colicinogenic activity.

Studies are underway to determine if the presence of colicin-producing bacteria in the mouse intestine will increase the resistance of the mice to pathogens susceptible to the colicin.

SOME ULTRASTRUCTURAL OBSERVATIONS OF THE GELATINOUS MATRIX OF THE UNICELLULAR GREEN ALGA, *HAEMATOCCUS*.

Danna Rosell and Harral Burris, Dept. Biology, University of Arkansas at Little Rock, Little Rock, Arkansas 72204

The presence of a distinct "gelatinous matrix" between the cellulosic cell wall and the plasma membrane distinguishes motile species of *Haematococcus* from the other unicellular genera of the Volvocales. Preliminary transmission electron microscopical observations of the gelatinous matrix in one or more species of *Haematococcus* will be discussed.

Ed. Note: This paper won the annual First Place award

SOME MICROSCOPICAL OBSERVATIONS ON GREEN AND APPARENT ALBINO SEEDLINGS OF THE TRIFOLIATE ORANGE, *PONCIRUS TRIFOLIATA*.

Betty Stallings, Dept. Biology, University of Arkansas, Little Rock, Arkansas 72204

A collection of seeds from a native Arkansas tree of trifoliate orange, *Poncirus trifoliata*, produced some apparent albino seedlings as well as the expected green seedlings. Histological preparations of leaves from both types of seedlings were examined with light and transmission electron microscopy. The most obvious differences between the two seedlings involved chloroplast structure. Preliminary observations on this aspect will be discussed.

DWIGHT M. MOORE

Dwight Munson Moore was born in Zanesville, Ohio, on December 10, 1891. He received a B.S. from Denison University, Granville, Ohio, and M.S. and Ph.D. degrees from Ohio State University. His education also includes study at the University of Montpelier, France.

Dr. Moore married Elizabeth Alice French on September 5, 1922. One child, a son - Dwight French, was born of this union. Dr. Moore married Clementine Winfrey on June 10, 1966.

Dr. Moore's wartime experiences include service with Hospital Train 58, U.S. Army, AEF in 1917-18, and he was a Sergeant, Medical Department, 1918-19. In 1944, during World War II, Dr. Moore was Regional Supervisor, Milkweed Floss Division, War Hemp Industries. This group was involved in collecting material that could be used in life jackets.

Dwight Moore began his teaching career as principal of Monroeville (O.) High School at which time he was also a teacher and a coach. He was an instructor of chemistry in the Zanesville High School, an instructor in Biology at Denison University, instructor in Botany at Ohio State University, and moved through the ranks from Assistant Professor to Department Head in the Botany Department of the University of Arkansas, Fayetteville. After becoming Emeritus Professor of Botany and Bacteriology, Dr. Moore taught in the Biology Department at Arkansas A & M College, Monticello, was a Smith-Mundt Professor at the University of Saigon, served as a Visiting Professor in a National Science Foundation Science Institute in Alaska, and was head of the Biology Department at Arkansas Polytechnical College, Russellville.

"Dr. Dwight" is a fixture of the Arkansas Academy of Science. He has been President three times, Vice-President once, Editor for twelve years, and Historian, as one Academy member said, "....since late Permian times." If anyone can claim to be "Mr. Arkansas Academy", it is Dwight Moore.

Robert T. Kirkwood
Historian

Editor's Note: We felt that by dedicating this volume of the Proceedings of the Arkansas Academy of Science to Dr. Moore, we could in some small way convey our appreciation for the many years of devoted service that he has given the Academy. We look forward to the continued participation and encouragement by Dr. Moore.

Scaled Chrysophyceae From Arkansas. II. The Genera *Mallomonas*, *Paraphysomonas* and *Spiniferomonas*

ROBERT A. ANDERSEN
Department of Botany and Bacteriology
University of Arkansas, Fayetteville 72701

ABSTRACT

This is the second paper of a floristic survey of the scaled Chrysophyceae of Arkansas and includes the following species: *Mallomonas crassisquama*, *M. cratis* var. *Asmundiae*, *M. papillosa*, *M. caudata*, *M. heterospina*, *M. insignis*, *Paraphysomonas vestita*, *P. imperforata* and *Spiniferomonas conica*.

INTRODUCTION

The morphology of the siliceous scales surrounding the cells continues to be the main distinguishing taxonomic feature for organisms placed in the family Synuraceae. This second paper continues the floristic survey of the scaled chrysophytes of Arkansas that has been previously initiated (Andersen and Meyer 1977).

METHODS

Samples were collected from several pools and ponds east of Fayetteville along Arkansas Highway 16 near Sequoyah Reservoir (Washington County), farm ponds along Arkansas Highway 170 north of Devil's Den State Park (Washington County), and De Gray Reservoir, an impoundment of the Caddo River (Clark County). Collections were made with a plankton net or Van Dorn water bottle and prepared for transmission electron microscopical study as described in the initial paper (Andersen and Meyer 1977).

RESULTS

Genus *Mallomonas* Perty 1851

The species assigned to this genus have been arranged into various groups based on the morphology of the scales (Conrad 1933; Huber-Pestalozzi 1941; Bourrelly 1957; Harris and Bradley 1960). The species discussed below are arranged according to Harris and Bradley's (1960) scheme which includes four series: Tripartiae, Planae, Quadratae and Torquatae. The series Tripartiae is further subdivided into three groups: acaroides, striata and papillosa. There is also an artificial cluster of species which do not fit into the four series.

Series Tripartiae
Group acaroides

Mallomonas crassisquama (Asmund 1959) Fott 1962, p. 79.
basonym: *M. acaroides* Perty 1851 emend Pascher 1910, Krieger 1930, Conrad 1933 var. *crassisquama* Asmund 1959, p. 32.
Plate III, Figure 19.

The validity of this taxon as a separate species has been questioned by Kristiansen (1975, 1976), and its relationship to *M. Bourrellyi* Teiling in Bourrelly 1957 is not clear. Thomasson (1963) published micrographs of scales from *M. Bourrellyi* which appear very similar to those of *M. crassisquama*. The cells of *M. Bourrellyi* are 22-38 μm by 12-14 μm (Bourrelly 1957) while the cells of *M. crassisquama* are smaller, 14-20 μm by 9-12 μm (Asmund 1959). The Arkansas material was collected from De Gray Reservoir, February 19, 1977. The cells and scales were very typical of *M. crassisquama*, and no "transitional" scales of the *M. acaroides* var. *striatula*-type were found.

Group striata

Mallomonas cratis Harris et Bradley 1960 var. *Asmundiae* Wujek et Van der Veer 1976, p. 181.
Plate I, Figures 1,6.

This variety was recently described by Wujek and Van der Veer (1976) from material collected in The Netherlands, and it is distinguished from the nomenclatural type by its parallel rib orientation on the dome rather than the u-shaped ribs of the type. It was collected on December 30, 1975, from an ephemeral pond located near Sequoyah Reservoir. The pond forms in an isolated woodland area following periods of extensive precipitation. It has trees throughout its confines; the water is dark brown in color and slightly acidic. The pond dried shortly after the collection and did not form again until February, 1978, but the species was not found again.

Group papillosa

Mallomonas papillosa Harris et Bradley 1957, p. 44 var. *papillosa*.
Plate I, Figures 5,7.

This species was found in a shallow pool near Sequoyah Reservoir during March, 1977. This pool also contained *Synura uvella* and *Mallomonas insignis*.

Series Planae

Mallomonas caudata Iwanoff 1899, p. 250 emend Krieger 1930, p. 294, Asmund 1955, p. 163.
synonyms: *M. fastigiata* Zacharias in Lemmermann 1899, p. 109.
M. fastigiata Zacharias 1903, p. 259.
M. fastigiata Zacharias 1903 var. *macrolepis* Conrad 1933, p. 65.
M. fastigiata Zacharias 1903 var. *Kriegeri* Bourrelly 1957, p. 187.

Plate II, Figures 8,9,10,13.

The taxonomy, and particularly the nomenclature, of this species is somewhat confusing (Fott and Ettl 1959; Asmund and Hilliard 1961). I agree with Asmund and Hilliard's (1961) retention of the name *M. caudata* because of the very incomplete description of *M. fastigiata* (Lemmermann 1899), the adequate description of *M. caudata* by Iwanoff in 1899 and the later descriptive but synonymous account by Zacharias (1903).

The armour of this species consists of numerous oval or circular scales, each with an attached bristle (Fig. 8,9,10). However, the connection between the scale and bristle is not siliceous but rather organic in nature, because the bristles are always separated from the scales during treatment with nitric acid. The acid treated bristle base, or "foot", is smooth and flattened (Fig. 13) with no evidence of an attachment point on the distal, unperforated end of the scale (Fig. 10).

This species has been found in two ponds near Devil's Den State Park during the fall of 1977, and was present in substantial numbers in both ponds. It has been reported from Arkansas on two previous occasions, once as *M. caudata* (Meyer 1969) and again as *M. fastigiata* (Meyer *et al.* 1970).

Mallomonas heterospina Lunc 1942, p. 274 emend Asmund 1956, p. 75.

Plate I, Figures 2,3,4.

Mallomonas heterospina is closely related to three other species: *M. multiunca* Asmund 1956, *M. pugio* Bradley 1964, and *M. Harrisae* Takahashi 1975. The scales of these four species can be distinguished by the shape of and ribbing pattern on the dome, the reticulate pat-

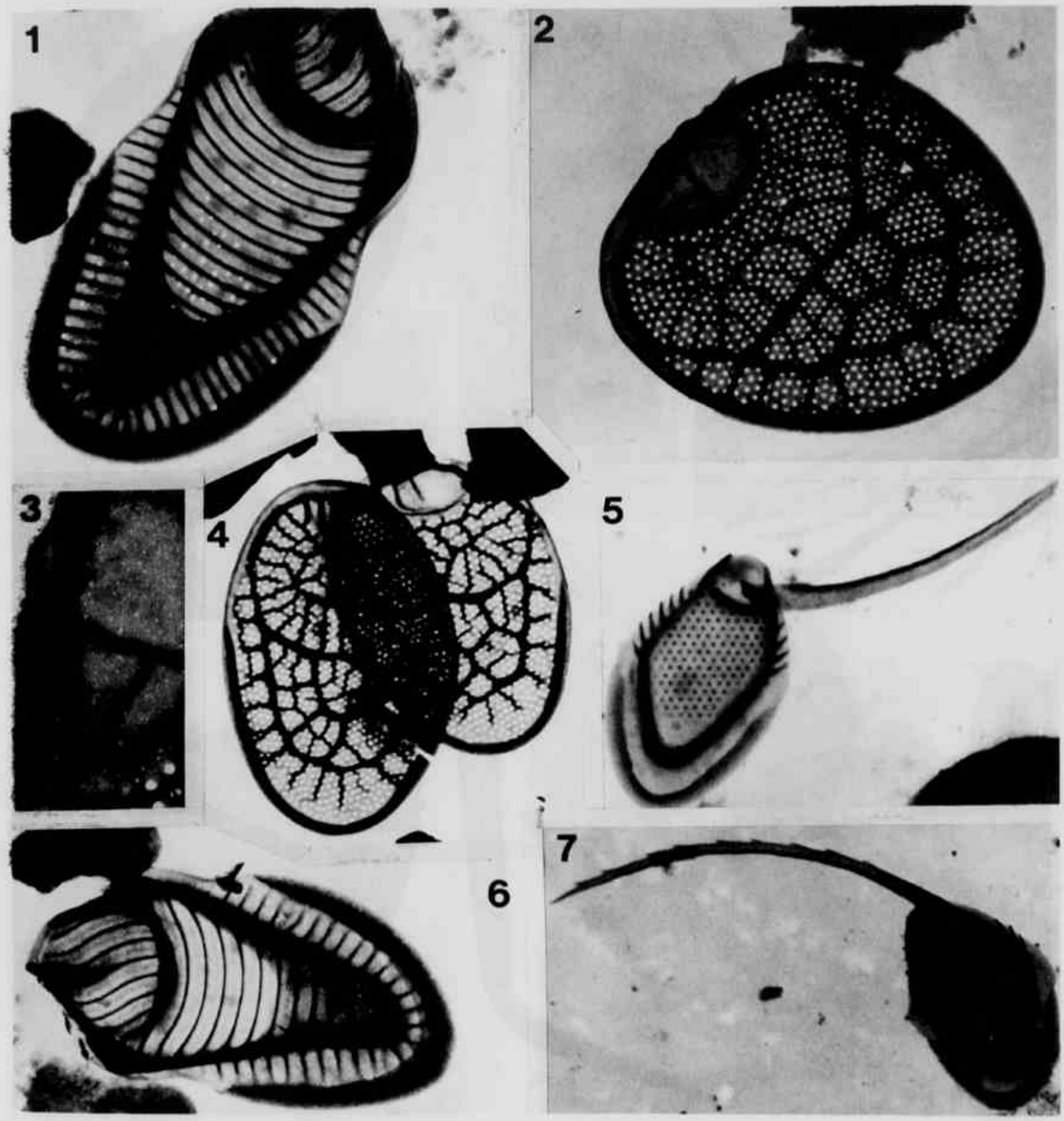

Plate I. Fig. 1. *Mallomonas cratis* var. *Asmundiae*, acid cleaned, 15,000 X. Fig. 2. *M. heterospina*, acid cleaned, 21,000 X. Fig. 3. *M. heterospina*, enlargement of dome area in figure 2, 42,000 X. Fig. 4. *M. heterospina*, acid cleaned, 15,000 X. Fig. 5. *M. papillosa*, 18,000 X. Fig. 6. *M. cratis* var. *Asmundiae*, acid cleaned, 15,000 X. Fig. 7. *M. papillosa*, 15,000 X.

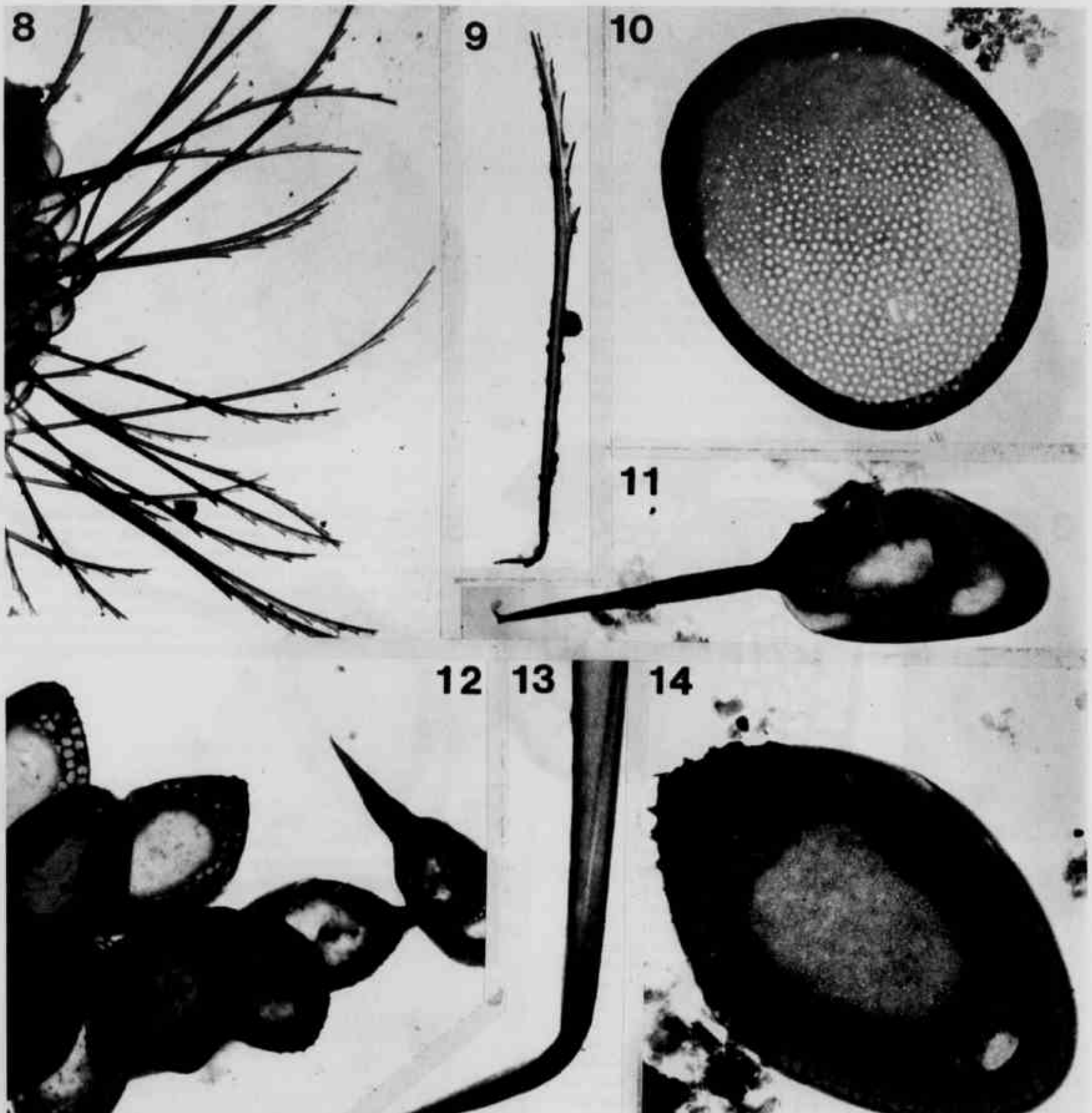

Plate II. Fig. 8. *Mallomonas caudata*. 1800 X. Fig. 9. *M. caudata*, bristle. 4500 X. Fig. 10. *M. caudata*, scale, acid cleaned. 12,000 X. Fig. 11. *M. insignis*, tailend scale, acid cleaned. 15,000 X. Fig. 12. *M. insignis*, apical and body scales. 4500 X. Fig. 13. *M. caudata*, acid cleaned bristle foot. 21,000 X. Fig. 14. *M. insignis*, body scale, acid cleaned. 12,000 X.

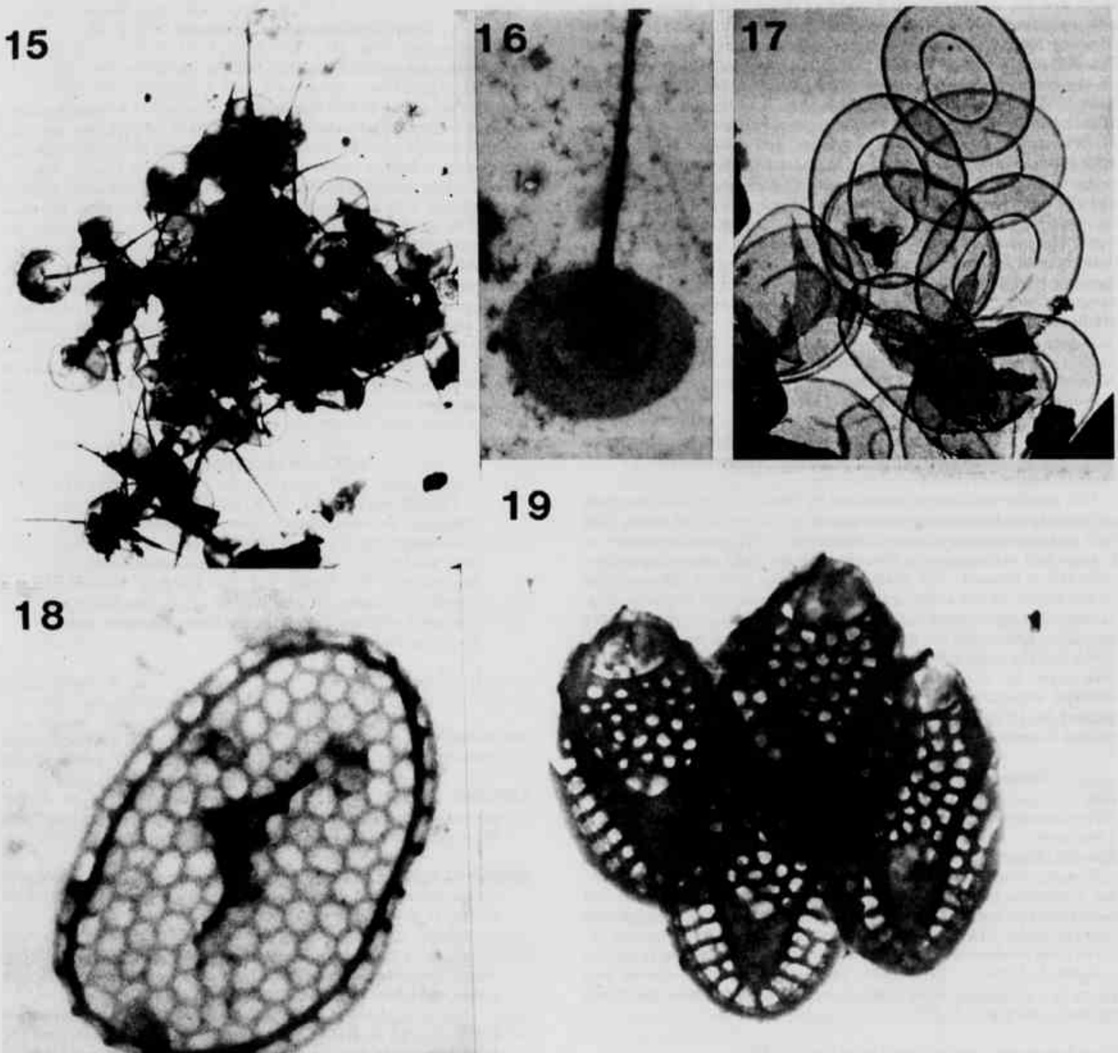

Plate III. Fig. 15. *Paraphysomonas vestita*, dried cell. 3300 X. Fig. 16. *P. imperforata*. 21,000 X. Fig. 17. *Spiniferomonas conica*, acid cleaned. 30,000 X. Fig. 18. *Paraphysomonas* sp. 30,000 X. Fig. 19. *Mallomonas crassisquama*. 9000 X.

terning and the type(s) of bristle(s) present. However, when this sample was digested with nitric acid, the bristles separated from the scales and no direct connections between the two were observed. Thus, the identification made here is based on the scale morphology only, but it should be mentioned that no hooked bristles were observed. The scales have some markings on the dome (Fig. 2,4), but these are not as heavy and distinct as those of *M. Harrisae*. And although the dome of *M. heterospina* has been described as smooth (Bradley 1964; Takahashi 1975), the micrographs of Asmund (1956, Fig. 3-5) and Wujek *et al.* (1975, Fig. 1) show similar light markings on the dome. Another character used to distinguish *M. heterospina* from *M. Harrisae* is the complete lack of hooked bristles on the latter (Takahashi 1975). However, Bradley (1964) reports juvenile cells of *M. heterospina* may lack hooked bristles, and Asmund (1956) found cells with an "almost total absence of hooked bristles." Thus, the differences between *M. heterospina* and *M. Harrisae* seem nebulous, and the difference used to distinguish these species in this case was the degree of thickness of the reticulate meshwork and dome striations. The meshwork and dome markings of *M. Harrisae* are thicker than those of *M. heterospina*. This species occurred in the same small woodland pond with *M. cratis* var. *Asmundiae*, and the temporary nature of this pond may have allowed only juvenile cells without bristles to form.

Species of Undesignated Series

Mallomonas insignis Penard 1919, p. 122.
synonyms: *M. torulosa* Kisselew 1931, p. 239.
M. mesolepis Skuja 1932, p. 28.
M. mesolepis Skuja 1932 var. *spinosa* Matvienko 1954, p. 90.
Plate II, Figures 11,12,14.

This species was clearly described by Penard (1919) and has more recently been thoroughly investigated by Harris (1958) using both light and electron microscopy. Organisms of this species are relatively large and rather easy to identify with the light microscope when their tail is present. The scales are likewise distinct. The cell has spined scales on the anterior (Fig. 12 - right side) and posterior (Fig. 11) ends and non-spined scales over the midbody region (Fig. 14, 12 - left side). The scales are described as hollow with a bent tip (Harris 1958), but the scale in Figure 11 appears to have a lateral tooth rather than a bent tip. The identification of this species has been verified by electron microscopy for collections from a woodland pond on December 30, 1975, and a small pool during March, 1977, both near Sequoyah Reservoir.

Genus *Paraphysomonas* de Saedeleer 1929, p. 177.

Paraphysomonas vestita (Stokes 1885) de Saedeleer 1929, p. 177.
basonym: *Physomonas vestita* Stokes 1885, p. 313.
Plate III, Figure 15.

Paraphysomonas vestita is a colorless, single-celled flagellate which, has numerous siliceous scales surrounding the protoplasm. It has been found in water of wide-ranging temperatures and hydrogen ion concentrations (Takahashi 1976), and in addition to numerous records from freshwater, this species recently has been found in marine samples (Leadbeater 1972, 1974; Thomsen 1975). This species was found in a collection from a small, temporary pool near Sequoyah Reservoir on March 9, 1977.

Paraphysomonas imperforata Lucas 1967, p. 330.
Plate III, Figure 16.

This species was described from a sample collected from the English Channel (Lucas 1967), but it has also been collected from freshwater in The Netherlands (Wujek and Van der Veer 1976). This appears to be the first record of the species in the western hemisphere. It was found in a sample collected from De Gray Reservoir on February 19, 1977.

Paraphysomonas sp.
Plate III, Figure 18.

Grids prepared from the De Gray Reservoir samples of February 19, 1977, contained scales which apparently belong to an undescribed species of *Paraphysomonas*. These scales are nearly identical to Takahashi's (1959) microplankton species number 13, and bear a superficial resemblance to *P. foraminifera* (Lucas 1967). The scales have a very regularly reticulated base which recurves up and in to produce a rim. There are solid triangular structures in the center of the scales, and these may represent either short or broken spines. Whole cells were not observed.

Genus *Spiniferomonas* Takahashi 1973, p. 76

Spiniferomonas conica Takahashi 1973, p. 79.
Plate III, Figure 17.

Scales belonging to this species were observed in a sample collected from a farm pond near Devil's Den State Park. There are two types of scales known for this species (Takahashi 1973). The elliptical scales have a hollow center and are about 1 μm in length. The two conical scales, partially hidden in the lower center of Figure 17, have a short spine with a capitate end projecting upward from the basal plate. The elliptical scales in Figure 17 agree with Takahashi's description (1973), but the spines of the conical scales are shorter. Takahashi describes the spine length to be 6.1 to 6.8 μm in length, and these are clearly several times longer than the elliptical scales in his Figures 21 and 22. Those collected from the farm pond have spines which are shorter than the elliptical scale length, and only about 0.6 μm in length. The type description is the only report of this species I have found. The slight difference in spine length reported here will probably be found to be within the limits of natural variation for the species.

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Some Physiological and Morphological Adaptations for Underwater Survival in *Natrix rhombifera* and *Elaphe obsoleta*

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ABSTRACT

The submergence times of the diamondback water snake (*Natrix rhombifera*) and black rat snake (*Elaphe obsoleta*) were compared. Both species could easily survive underwater for periods greater than one hour. Furthermore, there was no difference in time of underwater survival in the two species.

Some physiological and morphological parameters which may contribute to the ability of *N. rhombifera* and *E. obsoleta* to remain submerged were also examined. *E. obsoleta* was found to have a greater lung volume and larger and more numerous alveoli than *N. rhombifera*. Both species demonstrated a bradycardia upon submergence but it was less pronounced than the bradycardia of the true diving animals. It is concluded that *N. rhombifera* has few physiological adaptations for diving and that some of the physiological attributes for an aquatic existence have already developed in *E. obsoleta*.

INTRODUCTION

Representatives of all the major vertebrate groups display pronounced respiratory and cardiovascular changes when entering an aquatic environment. Many air breathers have the capacity to remain submerged for long periods of time and are physiologically and anatomically well suited to the diving situation. Most of the experimentation involving diving animals has been performed on birds and mammals, and virtually nothing is known of the diving physiology of water reptiles.

The ability of diving mammals and birds to remain submerged for prolonged periods of time is based on several interacting mechanisms. Pulmonary and myoglobin oxygen storage is greater in divers than nondivers (Scholander and Irving, 1941). There is a relative insensitivity of the respiratory center to carbon dioxide and lactic acid in divers (Irving, Scholander and Grinnell, 1941). An important circulatory adaptation in many diving birds and mammals is a very pronounced bradycardia (heart slowing) which occurs immediately after submergence. For example, in the seal the heart slows from a resting rate of about 80/min. to 10/min. during a dive (Scholander and Irving, 1941). Various circulatory shunts which maintain blood supply to the head and heart while occluding the supply to the rest of the body during submergence are found in some mammalian divers. The relative importance of all of these adaptations varies among diving mammals and birds.

The purpose of our study was two-fold. First, to discern if the diamond-back water snake, *Natrix rhombifera*, is better able to exist underwater than the terrestrial black rat snake (*Elaphe obsoleta*). Second, to examine some physiological and morphological parameters which may contribute to the ability of the two species to remain submerged.

METHODS AND MATERIALS

Natrix rhombifera were collected at night from various minnow farms located in Lonoke County, Arkansas. *Elaphe obsoleta* were collected during the daytime from wooded areas in Pulaski County, Arkansas. The weights of all experimental animals ranged between 500 and 800 g. Most of the snakes were utilized within one week of capture. Long term captives were fed leopard and bull frogs (Natrix) or small mice (*Elaphe*). All experiments were carried out between March and September, 1977, a period during which most snakes are normally active in Arkansas. The results of all experiments were analyzed by employing a Student's t-test. Values considered significant have a p value of 0.05 or less.

Dive Time Determinations

A 50 gallon tank was filled with tap water at 20°C. The snake was placed in a wire-mesh minnow cage which was then wired securely closed. The cage was lowered into the water leaving enough air at the top to allow the animal to breathe. Snakes were allowed normal activity which shortly would include diving. Time zero was recorded at the instant the snake voluntarily submerged its head at which point the cage was completely immersed. Animals were carefully observed throughout the experimental period. At the first sign of stress, which was always associated with frenzied attempts to reach the surface, the dive was terminated. After diving, the snakes were kept under close observation for approximately 30 min. to insure that they were not impaired as a result of the dive.

Lung Volume Determinations

Snakes were killed by exposure to chloroform. A mid-ventral incision was extended from the neck region, just posterior to the head, to the beginning of the small intestine. The heart, major blood vessels and a portion of the esophagus overlying the ventral aspect of the lung were then excised by blunt dissection. In most of the snakes dissected there was an intimate connection between the pleural membrane and the visceral membrane surrounding the liver. This often resulted in a perforation of the lung while trying to free it from the hepatic tissue. Consequently, the liver was left in place and didn't seem to interfere with the volume determinations.

Sealing the lungs to measure lung volume was accomplished by ligating the trachea just anterior to the lung with a piece of thread. A 50-ml syringe fitted with a 23 gauge needle was carefully inserted into the vascular portion of the sealed lung and any residual air remaining in the lung was slowly evacuated. After the lung was completely collapsed, the syringe was filled with exactly 50 ml of air and a second syringe (also filled with 50 ml of air) was inserted into the vascular portion of the lung at a distance of approximately 2 cm from the first syringe. Air from one of the syringes was slowly injected into the lung and if maximal lung expansion was not attained, the second syringe was slowly emptied to the point of maximal lung expansion. The point of maximal expansion was determined when there was a noticeable increase in resistance to the further addition of air. Overinflation was discernable by the formation of bulges or outpocketings particularly in the saccular portion of the lung. Lung volumes were expressed in terms of ml per g body weight.

Histology

The lungs were removed and rinsed in saline and then cut into small sections of approximately 1 mm thickness. The sections were placed in either Zenker's or AFA fixative for 72 hours. After fixation, the tissues were dehydrated with ethanol, cleared in xylene, and embedded in paraplast. Sections 8μ in thickness were cut with a rotary microtome and placed on slides. At this time the tissues that were fixed in Zenker's were stained with Mallory's triple connective tissue stain and the tissues that were fixed in AFA were stained with Harris' hematoxylin.

Heart Rate Determinations

The electrical activity of the heart was measured by means of EEG disc electrodes (Narco Bio-Systems, Inc., Houston, Texas). After experimenting with several different types of electrodes it was found that the EEG silver discs gave the most distortion free recording, were the easiest to attach, and caused the least discomfort to the animal. The two recording electrodes were placed approximately 1 cm lateral to the mid-dorsal line. Placement was such that one electrode was located directly above the thirty-second scute from the animal's anterior. The other electrode was lined up with the thirty-sixth scute from the animal's anterior. Previous dissections had revealed that the heart was located in the region between 32 and 40. A third electrode was placed on the animal's back more posteriorly to ground the system. The electrodes were connected to a cardiac preamplifier. The output from the preamplifier was directed into a Physiograph (Narco Bio-Systems, Inc., Houston, Texas) for recording.

The snakes were restrained with masking tape loosely wrapped around the body at intervals and then attached firmly to a flat surface. The head of the snake was inserted through a pliable rubber dam into a 2.5 cm diameter hollow glass tube. The tube was covered with a piece of dark cloth to reduce the possibility of disturbing the animal during the experiment.

RESULTS

Dive Times

There was no significant difference in the submergence time of the two species (Table I). Rat snakes maintained a high level of activity, swimming about the cage looking for a means of escape, throughout the dive period. The water snakes usually remained relatively quiescent until hypoxic stress became evident at which time there was increased activity in an attempt to reach the surface. In each species high levels of activity resulted in a decreased time of submergence.

The possibility of gas exchange across the skin was also investigated. In order to prevent possible cutaneous respiration, some snakes of both species were heavily coated with Vasoline Petroleum Jelly. In no instance did the Vasoline treatment reduce the submergence time, indicating the unlikelihood of cutaneous respiration.

Table 1. Dive times and lung volumes of *Elaphe obsoleta* and *Natrix rhombifera*

Species	Dive Time (min) mean ± SE (N)	Lung Vol. (ml/g body wt.) Mean ± SE (N)
E. obsoleta	70.5 ± 8.3 (9)	0.0803 ± 0.0125 (3)
N. rhombifera	68.3 ± 9.2 (10)	0.0510 ± 0.0111 (12)*

*Significant difference in lung volume at the 5% level.

Lung Morphology

In some primitive snakes the lungs are paired structures, whereas in other snakes there is a radical departure from this plan in that the left lung has been lost or is rudimentary with the right one remaining as the only respiratory unit. In *N. rhombifera* and *E. obsoleta* the right lung is a single tubular-shaped structure, and there are no remaining vestiges of the left lung.

A cartilagenous trachea begins just posterior to the head and extends into the pulmonary tissue. In the cardiac region there is an expansion of the respiratory tube which is the beginning of the lung. The first part of the lung is characterized by having a highly vascularized wall lacking any cartilagenous supports. Due to the rich blood supply, this first part of the lung is bright red in color and is called the vascular portion. The vascular portion of the lung comprised 27% of the total lung length in *N. rhombifera* and 36% of the total lung length in *E. obsoleta*.

Posteriorly, the vascular portion of the lung leads directly into the saccular portion. The saccular portion is also a cylindrical tube, slightly smaller in diameter than the vascular portion. It is poorly vascularized and appears white in color. Posteriorly, the saccular portion of the lung extends to different lengths in the two species. In *E. obsoleta* it was greatly extended, reaching to the gallbladder, whereas in *N. rhombifera* it reached its maximum extension several cm anterior to the gallbladder. *E. obsoleta* was found to have a 36.5% greater total lung volume than *N. rhombifera* (Table 1).

All of the tissue within the vascular portion of the lung surrounded one large chamber without internal septa. Scanning electron microscopy revealed that the inner surface of the vascular portion had a grid-like appearance. Light microscopy demonstrated that the grids were bundles of smooth muscle and the spaces between the grids were diverticula that extended into the lung tissue. The diverticula branched, became smaller, and eventually terminated in alveoli.

The alveoli in both species were polygonal in shape and consisted of a single layer of squamous epithelium. Surrounding the alveoli was an extensive capillary network. A very thin layer of connective tissue was located between the epithelium of the alveoli and the endothelium of the capillaries. The alveoli of *E. obsoleta* were both larger and more numerous than those of *N. rhombifera* (Table 2).

Table 2. Summary of alveoli characteristics in *Elaphe obsoleta* and *Natrix rhombifera*

Species	Number (mm^2) Mean ± SE (N)	Diameter (μ) Mean ± SE (N)
E. obsoleta	28 ± 4.5 (10)*	182 ± 22.6 (10)*
N. rhombifera	18 ± 6.6 (10)	84 ± 12.7 (10)

*Significant difference at the 5% level.

The saccular portion contained no alveoli and was composed primarily of connective tissue and a layer of muscle surrounding a single undivided lumen. The muscle layer was composed of smooth muscle cells interspersed with connective tissue.

Diving Bradycardia

Insertion of the snake's head through the rubber dam invariably resulted in a temporary tachycardia. This was particularly true the first time a particular snake was measured. After the first measurement the snakes demonstrated a remarkable acclimation to the experimental procedure, and the increase in heart rate was barely perceptable by the third or fourth measurement. The heart rate was always allowed to stabilize at its lowest value before any data was recorded.

After the heart rate stabilized, approximately 100 ml of tap water (20°C) was poured into the open end of the glass tube. This volume of water was sufficient to completely immerse the snake's head. Recording began immediately upon submergence and continued for 15 min. or until the animal became active. A pronounced bradyardia varied between snakes and even varied somewhat in the same snake on different dives. In all cases, however, bradycardia developed within one minute of submergence.

During the first three minutes of the dive there was considerable variation in the interval between heart beats, but after four minutes this variation disappeared. Within the first minute of submergence all the snakes exhaled. The bradycardia became much more noticeable after the initial exhalation and this could explain the variation in the onset time of bradycardia. In addition, any activity by the snake during the dive resulted in an increased heart rate which remained high for several minutes. Whenever a snake demonstrated any physical activity during a dive the experiment was terminated, and no data were recorded. Table 3 shows the percent reduction in heart rate of the two species 1 and 5 min. after submergence.

Table 3. One and five minute post-submergence bradycardia in *Elaphe obsoleta* and *Natrix rhombifera*. Heart rates (beats per min) are expressed as percent reduction from pre-dive rates.

Species	1 min.* Mean ± SE (N)	5 min.* Mean ± SE (N)
E. obsoleta	32.9 ± 9.6 (5)	44.7 ± 10.3 (5)
N. rhombifera	39.9 ± 8.6 (10)	57.2 ± 6.7 (10)

*Significant reduction from pre-dive heart rate at the 5% level.

DISCUSSION

Species Differences

It was commonly observed that inactive snakes could remain submerged for greater periods of time than could active ones under otherwise similar conditions. Submergence time seems to show an inverse relation to metabolic rate. For example, the submergence time was shortened by increased activity because of the higher metabolic rate under these conditions. During voluntary dives *N. rhombifera* was commonly observed quietly resting on the bottom for as long as 45 minutes. Even during the forced dives *Natrix* remained fairly inactive whereas the rat snake, in spite of a 36.5% larger lung volume, could not exceed the ability of the water snake to remain submerged.

Pickwell (1972) found that the sea snake *Pelamis platuris* tolerated 5 hours of being restrained underwater. Graham (1974) observed that some species of sea snakes had survival times ranging from 1.9 to 5 hours when they were held underwater in a wire cage. Interestingly, Graham found that the underwater survival time was directly porportional to the aquatic oxygen tension, which indicates that *P. platurus* can respire aquatically. It could take up to 30% of its total oxygen through the skin and could release carbon dioxide into the water at slightly higher rates. Our studies in which the snakes were coated with vasoline indicated that cutaneous respiration was not an important factor in prolonging underwater survival in either *N. rhombifera* or *E. obsoleta*.

The lung of *P. platuris* fills the coelomic cavity from the neck to the vent (Heatwole and Seymour, 1975). The lung volume in this species was found to be 0.58 ml/g body weight with the vascular portion comprising about 88% of the total lung length. In contrast, the lung volumes were much smaller in the two species we studied, and the vascular portion comprised only 27% and 36% of the total lung length in *N. rhombifera* and *E. obsoleta* respectively.

The involuntary submergence times in both *N. rhombifera* and *E. obsoleta* were much shorter than the reported values for sea snakes. The increased diving times of sea snakes are probably the result of specialized morphological and physiological adaptations not common to the species we studied. For example, the tremendous lung volume of sea snakes allows more oxygen storage for use underwater than is possible in either *N. rhombifera* or *E. obsoleta*. In addition, sea snakes can engage in a much higher rate of cutaneous respiration than can other snakes, again contributing to prolonged underwater survivability.

In both *N. rhombifera* and *E. obsoleta* the lung was clearly divided into two parts; a vascular portion and a saccular portion. All of the alveoli were located in the vascular portion which means that all gas exchange takes place in this portion. In reptiles it has been observed that lung volume increases in proportion to metabolic rate (Tenney and Tenney, 1970). The larger lung volume coupled with the larger and more numerous alveoli in the rat snake probably reflects a greater need for gas exchange in this active animal than in the relatively sedentary water snake.

The saccular portion of the lung contained no alveoli and, therefore, is not immediately involved in gas exchange. Brattstrom (1959) suggested the following functions for the saccular portion of the lung in snakes generally: (1) respiration, including both air storage and a flow through system, similar to the avian lung, permitting repassing of air over vascular areas during expiration; (2) cooling of the gonads by bringing cool air internally; and (3) body support, including a direct mechanical support and as a buoy in water. The air storage and buoyancy functions would be particularly important to water snakes.

McDonald (1959) suggested another possible significance of the saccular portion of the lung. He pointed out that if a cylindrical sac is elongated but the surface area is kept constant, its volume decreases. Thus, an elongation of the vascular portion of the lung imposed by the snake's body shape would limit the tidal volume and, hence, the amount of oxygen inspired, even though the total vascular surface might be adequate for gas exchange. McDonald suggested that the saccular portion provides a mechanism for increasing tidal volume and, thereby, compensating for the relative loss of lung volume in the elongated vascular portion. Furthermore, these considerations would apply equally well to water and terrestrial snakes and would explain the presence of a saccular portion in the lung of *E. obsoleta*.

The generalized lung plan of the snake might also be adaptive in other ways. For example, a large food bolus in the stomach might occlude the saccular portion of the lung, and an anterior shift of the vascular tissue would be an advantage. In addition, both *N. rhombifera* and *E. obsoleta* ingest large prey, and a saccular portion used for oxygen storage would be an advantage to both species during the swallowing process when respiration is interrupted. This is particularly true in view of the fact that the saccular portion contains smooth muscle which would allow a redistribution of air to the vascular portion during swallowing. The smooth muscle in the saccular portion may also be important in redistributing air from the saccular portion where it is stored to the vascular portion where gas exchange occurs during a prolonged dive.

Diving vertebrates including mammals, birds, reptiles, and amphibians display marked reductions in heart rate during submergence. This same response even occurs in non-divers such as man. Reptiles which have been shown to exhibit diving bradycardia include the crocodilians, fresh-water and marine turtles, terrestrial, semiaquatic and marine lizards and several species of aquatic snakes (Wilber, 1960; Belkin, 1964; Bartholomew and Lasiewski, 1965; Jacob and McDonald, 1976; Irvine and Prange, 1976; Heatwole, 1977).

In *N. rhombifera* and *E. obsoleta* there was a reduction in heart rate within one minute after submergence. The fact that the bradycardia was somewhat more pronounced in the water snake than in the rat snake is probably because submergence is a common occurrence in water snakes whereas it represents a rather unnatural event to the terrestrial rat snake.

The diving bradycardia exhibited by the "true" diving mammals such as seals and whales appears to be initiated by a nerve reflex since it develops within one heartbeat of submersion. The vagus nerve appears to be the efferent limb for this reflex because the response is prevented by the administration of parasympatholytic drugs like atropine (Prosser, 1973).

The changes in heart rate reported here probably do not represent a true diving bradycardia. True diving bradycardia is known to be insensitive to activity. In our experiments the diving heart rate was elevated in both species by moderate increases in activity. In addition, in true diving animals the bradycardia is extreme. For example, the heart rate of the South American caiman drops from a resting level of 25 to less than 5 beats per minute during a dive (Gaunt and Gans, 1969). In our study the reduction in heart rate was only 45 to 57% of normal, values comparable to non-diving animals including man. Finally, in true diving animals the bradycardia begins within one heartbeat of submersion, whereas in our study bradycardia sometimes did not become noticeable until one or two minutes after the dive began, and was never evident immediately after the first heart beat in either species. Thus, the diving heart rate in *N. rhombifera* and *E. obsoleta* should not be considered comparable to the bradycardia exhibited by the true diving animals.

In summary, the surprising thing about the water snake, *N. rhombifera*, is that is appears to have few physiological adaptations for diving. The survival time of *Natrix* when forceably submerged is no longer than that of the terrestrial rat snake, and is much shorter than some fresh-water and marine turtles and the sea snakes which can remain under water for several hours. Furthermore, the lung volume in *Natrix* is somewhat smaller than that of terrestrial snakes and is a great deal smaller than that of the sea snakes. In addition, *Natrix* does not seem to have any capacity for cutaneous respiration as do several species of sea snakes. Finally, the bradycardia recorded in *Natrix* during a dive was similar to that of the terrestrial rat snake and was much less than the reductions in the heart beat demonstrated by the true diving reptiles.

Based on lung morphology, underwater tolerance, and diving bradycardia it would seem that much of the physiological potential for an aquatic existence has already developed in the rat snake and presumably in other terrestrial species as well. In this regard, it is surprising that the evolutionary transition from a terrestrial to an aquatic existence has occurred so infrequently among the snakes.

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Effects of Hypobaric Hypoxia on Some Enzyme Systems in the Mammalian Liver

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ABSTRACT

The metabolic effects of hypobaric hypoxic stress on the mammalian liver were studied. The lactate dehydrogenase (LDH) and succinate dehydrogenase (SDH) activity of mouse liver homogenates were measured after exposure to an equivalent altitude of 36,000 feet and compared to controls kept at zero altitude. After six and twelve hour incubation periods, the altitude exposed samples demonstrated a significantly higher LDH activity than controls. SDH activity remained unchanged from controls after six hours but was significantly lower than controls after a 12 hour exposure to altitude. It is concluded that the changes in enzyme activity reflect a metabolic control mechanism attempting to maintain adequate energy production during periods of exposure to hypobaric hypoxic stress.

INTRODUCTION

It is well known that many physiological changes occur in animals during periods of exposure to high altitudes. Over a period of time, some of these changes include hyperventilation, increased vascularity, and increased hemoglobin. These changes can be considered compensatory reactions and are known to aid in the survival of man and other organisms during periods of exposure to lowered oxygen partial pressure at altitude, a condition known as hypobaric hypoxia.

The biochemical mechanisms that regulate the adaptation of animals to environmental stress like hypobaric hypoxia are not clear at the present time. Exposure to hypobaric hypoxia could result in a lowered oxygen tension in the tissues, thus, seriously affecting those metabolic processes which are dependent on molecular oxygen. The biochemical and physiological responses to altitude exposure should favor the development of compensatory mechanisms to overcome the effects of the stress.

Several attempts have been made to determine if exposure to altitude results in changes in cellular metabolism. For example, the oxygen storage pigment, myoglobin, from both cardiac and skeletal muscle has been shown to increase during prolonged exposure to altitude (Anthony et al, 1959). There are also a number of reports on the effects of altitude exposure on tissue respiration. There is some controversy, however, concerning the findings of these reports. Some workers have reported that tissue respiration is decreased during altitude exposure (Clark et al, 1954); others have claimed that it is increased (Sundstroem and Michaels, 1942); while still others have claimed that it is unchanged (Frehn and Anthony, 1961).

Our study was undertaken in the hope of clarifying some of the contradictory findings concerning cellular metabolism during exposure to altitude. The specific aim was to examine the effects of hypobaric hypoxia on two hepatic enzymes in the mouse: lactate dehydrogenase (LDH) and succinate dehydrogenase (SDH). By examining the activities of these two enzymes, it was possible to quantitate the effects of hypobaric hypoxia on the activity of both the Embden-Meyerhof pathway and the tricarboxylic acid cycle.

There are several problems encountered in trying to deduce the effects of hypobaric hypoxia on the tissues of animals after *in vivo* exposures to altitude. A particularly important problem is the different effect of hypobaric hypoxia on the blood flow to different organs. For example, severe hypobaric hypoxia results in a dramatic increase in coronary blood flow (Hackel et al, 1954) but only a moderate increase in cerebral blood flow (Lassen, 1959). It is clear that, due to these differences in perfusion, the actual degree of lowering of the intracellular oxygen tension cannot be predicted from most *in vivo* experiments. In light of this observation, the study of the effects of hypobaric hypoxia on a particular tissue can only be accomplished under conditions of complete ischemia or of controlled blood flow. By employing an *in vitro* approach in our study it was possible to circumvent the problem of perfusion changes and at the same time to quantitate the direct effects of hypobaric hypoxia on hepatic cellular metabolism.

METHODS

Female adult Swiss Webster mice (approximate weight 35-40g) were used in all experiments. Mice were killed by cervical dislocation, and pieces of liver weighing approximately 150 mg for the LDH assay or 450 mg for the SDH assay were removed. The tissues were homogenized by a Polytron tissue homogenizer (Brinkman Instruments, Westbury, New York) after addition of 0.1 ml of phosphate buffer (0.034M, pH 7.4) to 1 mg of tissue for LDH and 5 mg of tissue for SDH, respectively.

The homogenate was centrifuged (Beckman model LZ-50 Ultracentrifuge) at 20,000 RPM for five minutes after which the supernatant was removed and placed on ice. For incubation, 100 µl of the supernatant was added to each of 32 1-ml capacity incubation vials. Each incubation vial was tightly capped to prevent evaporation. The rubber middle of each cap was pierced by an 18 gauge hypodermic needle for the purpose of pressure equalization during the hypobaric treatments.

The incubation vials were divided into two groups, the controls and the experimentals. The control vials were placed in a desiccator containing filter paper dampened with water and were incubated at ambient barometric pressure. The experimentals were placed in a 9.3 liter capacity glass vacuum desiccator containing dampened filter paper. A Diaphragm Air Pump (model PV-200, Bell & Gossett-Leiman Bros., Monroe, LA) was used to create a vacuum equivalent to 23 inches of Hg (altitude equivalent, 36,000 ft) in the experimental desiccator. Both the control and experimental tissue samples were incubated for periods of 0,6 or 12 hours. For the 6 and 12 hour incubations, the samples were maintained at a constant 4°C temperature.

Lactate dehydrogenase activities of the liver homogenates were determined by the method of Worthington (Worthington Biochemical Corporation, Freehold, NJ). Following incubation, the LDH activities of the homogenates were determined by measuring the spectral conversion of $NADH_2$ to NAD on a recording spectrophotometer (model 25, Beckman Instruments, Inc., Fullerton, CA) at a wavelength of 340 mµ at 20°C. The assay medium consisted of 2.7 ml phosphate buffer (0.034M, pH 7.4), 0.1 ml $NADH_2$ (0.0027M, pH 8.0) and 0.1 ml sodium pyruvate (0.01M, pH 7.0). At time zero 25 µl of the liver homogenate was added to the assay medium in a quartz cuvette and vigorously mixed. The changing optical density in the sample cuvette was compared to a blank (assay medium with 0.1 ml distilled water substituted for $NADH_2$, plus 25 µl of tissue homogenate) for a 1.5 minute period.

The SDH activities were determined by measuring the spectral reduction of ferricyanide at a wavelength of 400 mµ (Kim and Han, 1969) at 20°C. The assay medium consisted of 0.3 ml of potassium cyanide (0.1M, pH 7.0), 0.3 ml potassium ferricyanide (0.01M), 0.4

ml of sodium succinate (0.5M), and 2.0 ml of Tris buffer (0.3M, pH 7.6). At zero times 25 μl of the liver homogenate was added to the assay medium in a quartz cuvette and thoroughly mixed. The changing optical density was compared to a blank containing the assay medium without the enzyme for a period of two minutes.

Protein determinations were done by a modification of the method of Lowry (Oyama and Eagle, 1956). Enzymatic activity is expressed in terms of μ moles of succinate or lactate converted/min/mg protein. Multiple comparisons of the means of enzyme activities were done by means of a Newman-Keuls statistical test. Values considered significant have a p value of 0.05 or less.

RESULTS

Recorded in Tables I and II are the mean changes in enzyme activity for LDH and SDH, respectively. Since there were no significant differences between the control and experimental tissue homogenates for the 0 hour incubation periods, it can be concluded that hypobaric hypoxia has no immediate effects on the enzymes. After 14 hours there was a significant decrement in enzymatic activity in both the control and experimental tissue homogenates; therefore, incubation periods were limited to 12 hours.

After a 6-hour incubation period, the LDH activity of the experimental tissue homogenates was significantly higher than that of the controls and the same trend was maintained for the 12-hour incubations. In the case of SDH, both the control and experimental tissue homogenates after 6 hours showed an increased activity over those incubated for 0 hours. There was no significant difference in the SDH activities between tissues incubated for 12 hours and those incubated for 0 hours. After 6 hours the SDH activity of the control homogenates was slightly higher than the experimentals. Between 6 and 12 hours there was a decrease in SDH activity in both experimental and control tissue homogenates, and after 12-hour incubations the activities of the experimentals were also significantly lower than the controls. The experimental results for both LDH and SDH activities are graphically depicted in Figures I and II, respectively.

Table I. Mouse liver lactate dehydrogenase activity as influenced by hypobaric hypoxia. LDH activity determinations were made at a wavelength of 340 mμ at 20°C and are expressed in terms of μm of enzyme/min/mg protein

INCUBATION PERIOD (hours)	CONTROL (P_{O_2}=158.5mmHg) Mean ± SE (N)	EXPERIMENTAL (P_{O_2}=35.9mmHg) Mean ± SE (N)	%CHANGE
0	10.31 ± 1.52 (47)	10.27 ± 1.50 (48)	-0.4
6	9.14 ± 0.99 (86)	9.92 ± 1.08 (85)*	+7.9
12	8.90 ± 1.31 (47)	9.40 ± 1.39 (47)*	+5.4

*Significant difference in SDH activity at the 5% level.

Table II. Mouse liver succinate dehydrogenase activity as influenced by hypobaric hypoxia. SDH activity determinations were made at a wavelength of 400 mμ at 20°C and are expressed in terms of μm of enzyme/min/mg protein.

INCUBATION PERIOD (hours)	CONTROL (P_{O_2}=158.6mmHg) Mean ± SE (N)	EXPERIMENTAL (P_{O_2}=36.0mmHg) Mean ± SE (N)	%CHANGE
0	0.4567 ± 0.0681 (46)	0.4472 ± 0.0666 (46)	-2.1
6	0.5186 ± 0.0615 (72)	0.4920 ± 0.0584 (72)	-5.2
12	0.4484 ± 0.0654 (48)	0.3891 ± 0.0574 (47)*	-13.3

*Significant difference in LDH activity at the 5% level.

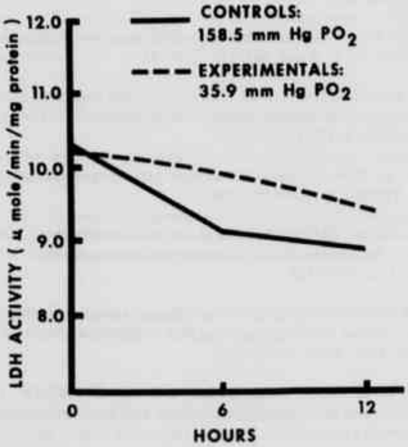

Figure 1. Lactate dehydrogenase activity (μ moles/min/mg protein) of mouse liver homogenate as influenced by hypobaric hypoxia (35.9 mmHg P_{O_2}) and normobaric oxygen tensions (158.5 mmHg P_{O_2}) at 20°C. Plotted are the means. Refer to Table I for statistical details.

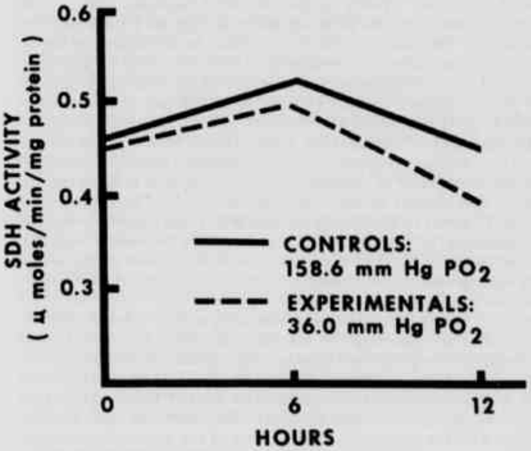

Figure II. Succinate dehydrogenase activity (μ moles/min/mg protein) of mouse liver homogenate as influenced by hypobaric hypoxia (36.0 mmHg P_{O_2}) and normobaric oxygen tensions (158.6 mmHg P_{O_2}) at 20°C. Plotted are the means. Refer to Table II for statistical details.

DISCUSSION

The specific increase in SDH activity in both the experimental and control liver tissue homogenates may be of physiological significance. In the case of the experimental homogenates, the available oxygen is decreased. In a 6 hour exposure to such conditions the enzyme systems might have to be regulated to meet the energy requirements of the cell. In the mammalian liver the limiting enzyme in the sequence of electron transport is SDH; therefore, this is the obvious site for a change to increase the overall rate of cellular respiration despite the lowered oxygen concentration. In this context the modulation of the rate limiting SDH activity to increase the overall rate of oxidation of succinate would become meaningful to maintain the energy requirements of the cell. The increase in the SDH activity of the control homogenates after 6 hours is more difficult to explain. The increased activity is not likely a response to hypoxic stress, but is probably a metabolic response to the unavoidable stress of the *in vitro* situation.

The fact that SDH activity decreases after exposures to hypobaric hypoxia as compared to controls exposed to normobaric oxygen tensions suggests that other mechanisms may be occurring. In a study by Aschenbrenner et al. (1971) in which mice were exposed to 4-5% O_2 for 6 hour periods, it was found that there was a significant decrease in cardiac muscle mitochondria. It was concluded that tissue oxygen tension is a potent regulator of mitochondrial functional mass in mammalian cardiac muscle. The reduction in hepatic SDH activity after a 12 hour exposure to hypobaric hypoxia in our experiments may reflect a similar reduction in functional hepatic mitochondria.

Bartley et al. (1968) observed that during periods of oxygen deficiency there is a decrease in phospholipid synthesis for mitochondrial membrane formation. Phospholipids have specific effects on the catalytic efficiency of certain enzymes. Phospholipids are not only necessary for the activity of the succinoxidase system and various fragments of the electron transport chain but they are also necessary to maintain the activity of SDH (Hafkenscheid et al., 1963). The effect of phospholipids on SDH occurs at the level of the enzyme molecule either by producing a favorable medium for the reaction or by modifying the protein (Cerletti et al., 1965). The decrease in SDH activity upon exposure to altitude in our experiments may be the result of a decrease in phospholipids.

There have been numerous studies attempting to elucidate the effects of hypobaric hypoxia on mitochondrial function. After a continuous exposure of rats to a simulated altitude of 25,000 feet for several days, there were significant decreases in the respiratory capacity of liver and kidney mitochondria (Gold et al., 1973). In addition, Strickland et al. (1962) observed a decline in the respiration rate of liver mitochondria from rats exposed to 21,000 feet for 6-7 weeks. Nelson et al. (1967) found a decrease of 15% in the same parameter in rats exposed to 25,000 feet for 3 days. On the basis of these collective *in vivo* findings, it appears that mitochondrial respiratory activity falls relatively early in chronic altitude stress and remains below normal. The present *in vitro* study has shown that an exposure as short as 12 hours to an altitude of 36,000 feet can result in a significant decrease in hepatic SDH activity. This hypobaric hypoxic induced decrease in SDH activity, if not compensated for by some other mechanism, would similarly result in a decreased respiratory activity of the hepatic homogenates.

Hypoxia has been found to produce oxygen debt, raise the lactate to pyruvate ratio and result in the accumulation of excess lactate in the blood of several different species of experimental animals including man (Huckabee, 1965 and Gold et al., 1973). In our experiments there was a significant increase in LDH activity after exposure to hypobaric hypoxia for 6 and 12 hours. This increased LDH activity coupled with the decreased SDH activity of the experimental tissue homogenates may be part of a cellular control mechanism to maintain metabolic efficiency during hypobaric hypoxic stress. Although the respiratory capacity of the mitochondria is lowered, there may not be a decrease in the total energy production of the cell. The increase in LDH activity intimates an increase in the glycolytic rate of the cell. Thus, there is a metabolic compensatory mechanism at work attempting to maintain adequate energy production during exposure to hypobaric hypoxia.

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Range and Status of the Nutria, *Myocastor coypus*, in Arkansas

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ABSTRACT

An extensive survey has shown that the current range of the nutria, *Myocastor coypus*, in Arkansas should include the West Gulf Coastal Plain, the Mississippi Alluvial Plain (to Missouri) and the Arkansas Valley along the Arkansas River to Oklahoma. The extensive river and creek systems in the state have provided ready avenues for dispersal, allowing for extremely rapid expansion from the early 1960's when nutria were first observed in the southern part of the state. The current range probably represents most of the suitable habitat in the state and it is felt that further expansion will be held to a minimum.

INTRODUCTION

Since its importation from South America into the United States the nutria *(Myocastor coypus)* has been the subject of considerable controversy. Proponents argue that it is an important furbearer and controller of aquatic weeds, while others argue that it does great damage to dikes and levees, destroys crops (especially rice, soybeans, and sugarcane), and contributes to the decline of the muskrat (another important furbearer). These arguments seemingly have no solution, and evidence can be found supporting both views; however, the nutria is more often considered a pestiferous mammal (Evans, 1970; Lowery, 1974; Warkentin, 1968).

Nutria were first introduced into the marshes of Louisiana, near New Orleans, in the early 1930's; however, these were all recovered or trapped. In 1938, twenty more were imported from Argentina and placed in a nutria ranch on Avery Island, Louisiana, only to escape or to be released. By the middle 1940's they were extremely common in the southern half of the state and by the late 1950's had quickly spread to all parts of the state (Lowery, 1974).

It appears that the nutria entered the southern part of Arkansas in the early 1960's. Since that time they have rapidly extended their range and have been recorded throughout the southern and eastern portions of the state. The purpose of this study was to determine the current range and status of the nutria in Arkansas and to speculate on future trends.

METHODS AND MATERIALS

The methods of obtaining the data for this study included:

1) Interviewing personnel and examining records of the Arkansas Cooperative Extension Service and the Arkansas Game and Fish Commission.

2) Soliciting records from the collections of neighboring universities and institutions.

3) Selective telephone polling of persons in Arkansas likely to have come in contact with nutria.

4) Surveying (using a questionnaire) Game and Fish field personnel, county extension agents and Arkansas fur buyers and trappers. These questionnaires requested pertinent information concerning the nutria such as localities nutria were found in, dates seen, population levels and trends, and damage done by nutria.

RESULTS AND DISCUSSION

Table 1 summarizes the distribution and return of the questionnaires mailed around the state. The relatively low percentage of return (36%) can be explained by the limited response of the Arkansas fur buyers and trappers surveyed.

The presence of Arkansas nutria in scientific collections is limited. The Arkansas State University Collection of Recent Mammals contained three specimens (including a first record from Jackson and Cross Counties) and the University of Arkansas at Little Rock Vertebrate Collections contained five specimens.

Figure 1 summarizes the findings by county and Figure 2 illustrates the current range of the nutria in Arkansas according to these results. In Figure 2, Izard and Madison Counties are omitted since the only positive report was one nutria in each of the counties, which appeared on two Game and Fish Commission fur buyers' reports. It is entirely possible that these two animals came from other parts of the state. We have also included Poinsett, Lee, Cleveland, and part of Pike Counties in Figure 2, since there are nutria in the major river and stream systems on either side and flowing through these counties.

We feel, however, that the range of nutria in the state of Arkansas should be as indicated in Figure 3. This area encompasses the Mississippi Alluvial Plain, the West Gulf Coastal Plain, and parts of the Arkansas River Valley. In addition to those counties included in Figure 2, Clay, Green, and parts of Sebastian, Crawford, Perry, Conway, Faulkner, and Logan Counties are added. These areas have suitable habitat and are natural expansion sites (assuming nutria are not already present in low numbers).

The presence of the isolated area in the Arkansas River Valley in Figure 2 is cause for speculation. Nutria could have expanded into this area in one of two ways. It has been reported (Sealander, *pers. comm.*) that nutria were released near Fort Smith, Sebastian County, several years ago. These animals could have moved south and east along the Arkansas River becoming established in the areas outlined. This suggests that perhaps small and isolated populations already exist in Sebastian, Crawford, and Logan Counties. On the other hand, nutria could have expanded from the east moving up the Arkansas River. This would suppose that nutria exist in small, scattered areas along the river in Perry, Faulkner, and Conway Counties. Whichever is the case, it is reasonable to assume, considering past trends, that these areas should be included in the overall range as shown in Figure 3.

The rate of nutria expansion in Arkansas has been extremely rapid. From 1960 to the mid 1970's the species has spread over 390 km northward. This represents a conservative average invasion rate of between 20-24 km/yr. However, it has generally been shown that introduced species invade faster than nonintroduced. For example, the rabbit *(Oryctolagus cuniculus)* invaded Australia at rates between 24.6-63.8 km/yr (Myers, 1970), and the muskrat *(Ondatra zibethicus)* invaded Czechoslovakia at rates of up to 16.7 km/yr (Elton, 1958). In contrast, examples of invasion rates of non-introduced species include from 4-10 km/yr in the armadillo *(Dasypus novemcinctus)* in the United States (Humphrey, 1974), 7.5 km/yr in the polecat *(Mustela putorius)* in Finland (Kalela, 1940), and 8.1-12.3 km/yr in the cotton rat *(Sigmodon hispidus)* in Kansas (Cockrum, 1948). In the case of the nutria in Arkansas, the ideal river and stream systems which form natural dispersal routes and habitat, the lack of natural predators such as the alligator, the agricultural irrigation methods of open ditches with levees, and the favorable climate over the 1960's and 1970's greatly enhanced the opportunity to expand at a rapid rate.

Nutria appear to be most solidly established in the West Gulf Coastal Plain (particularly the southern portion) and the southern and eastern Delta of the Mississippi Alluvial Plain. The populations in the western part of the Mississippi Alluvial Plain and the Arkansas River Valley appear to be small and highly scattered. We feel that populations will remain relatively low in these areas due to greater marginal habitat, changing agricultural practices (e.g., open water being replaced by irrigation pipes), and perhaps changing climate bringing colder, more prolonged winters.

The price of fur seems to have a decisive effect on the trapping of nutria in the state, as can be seen in Table 2. During the early 1970's, when the price of nutria pelts was low, few nutria were trapped. In the 1976-77 season when fur prices were higher so were the numbers of nutria trapped. However, this increase might have been brought about partially by a rising population level. Table 2 also shows when nutria first began to be trapped in the Arkansas River Valley. If the price of fur remains stationary, it will be interesting to see what influence the trappers have on locating new marginal populations as well as the effect on the overall size of existing nutria populations. It should also be mentioned that if the current restocking of the alligator in the state by the Game and Fish Commission is a success, the nutria will have to contend with a natural predator in the future.

Figure 1. County Response to Nutria Study in Arkansas.

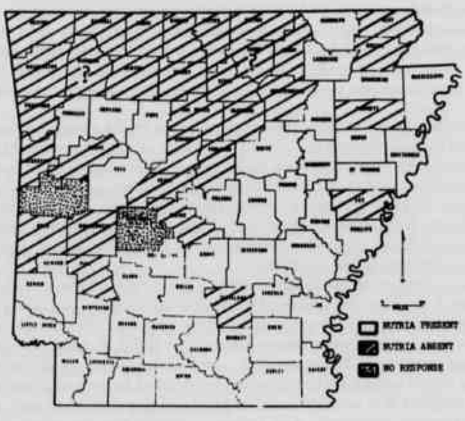

Figure 2. Current Range of the Nutria Based on Data Gathered by Study.

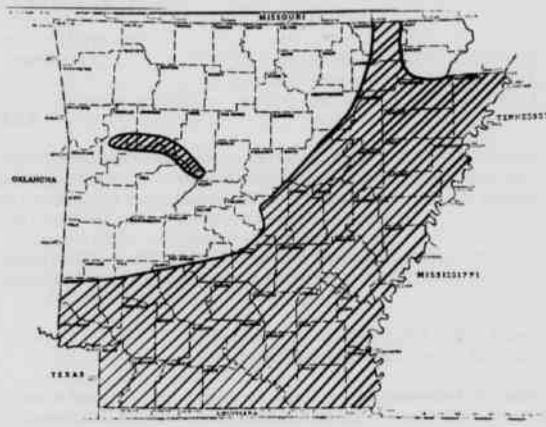

Figure 3. Proposed Range of the Nutria, *Myocastor coypus*, in Arkansas.

Table I. Arkansas Nutria Questionnaire Summary

Agency or Individuals Contacted	# Sent	# Returned	% Return
County Extension Agents	51	29	57
Game and Fish Personnel	37	25	68
Arkansas Fur Buyers and Trappers	117	20	17
TOTAL	205	74	36

Table II. Harvest Report of Arkansas Fur Dealers 1970-77

	1970-71	71-72	72-73	73-74	74-75	75-76	76-77	Total
Average Price	0	0	$2.16	$1.38	$1.78	$1.20	$3.01	$1.91*
Delta Region	0	0	23	4	3	13	470	513
Ozark Region	0	0	0	9	0	0	151	160
Ouachita Region	0	0	0	0	0	0	62	62
West Gulf Coastal Plain	77	0	10	6	107	79	547	826
Totals	77	0	33	19	110	92	1230	1561

*Average for 1972-77.

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Depositional Systems of the Sells and Cecil Sandstones, Atoka Formation (Pennsylvanian), Eastern Crawford And Western Franklin Counties, Arkansas

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ABSTRACT

The Cecil and Sells sandstones of the Atoka Formation (Pennsylvanian) were studied in the subsurface of eastern Crawford and western Franklin Counties. Sand of the Cecil sandstone was delivered to a high destructive, wave dominated delta southeast of Fort Smith and reworked laterally by longshore currents to form coastal barrier sands to the east. The Sells sandstone unit accumulated as a distributary channel system that bifurcates to the southeast and southwest. The interdistributary areas are characterized by immature sands interbedded with shales. These immature sands were deposited by crevasse splays and reworking of the distributary mouth bars by marine processes causing sand transport into the interdistributary areas.

INTRODUCTION

The lower part of the Atoka Formation (Pennsylvanian) in eastern Crawford and western Franklin Counties, Arkansas, is a succession of sandstone and shale units. Data from 118 mechanical well logs were used to establish the depositional systems of the Cecil and Sells units. The gamma ray and resistivity curves were used to determine the thickness and well log signature of the sandstone units. Isopach and well log signature maps were constructed and used to establish the depositional systems important in the emplacement of these sandstones. The Cecil and Sells sandstone units accumulated on the continental shelf of the Arkoma Basin. Basinward shale deposition was simultaneous with sandstone deposition.

REGIONAL STRUCTURE

The Arkoma Basin is north of the Ouachita overthrust belt and is characterized by east trending anticlines and synclines. Dips on the flanks of these structural features decrease in magnitude toward the northwest Arkansas structural platform and are only a few degrees in the northern part of the basin. The Arkoma Basin is separated from the northwest Arkansas structural platform by large east trending normal faults which displace lower Atoka strata into the subsurface to the south (Diggs, 1961).

REGIONAL STRATIGRAPHY

Regionally the Atoka Formation is underlain on the northwest Arkansas structural platform and in the Arkoma Basin by the Bloyd Formation. In the Arkoma Basin the Atoka Formation is overlain by the Hartshorne Sandstone. The Atoka Formation thickens from a featheredge on the northwest Arkansas structural platform to cover 20,000 feet in the Arkoma Basin (Branan, 1968).

AREA OF INVESTIGATION

The Cecil and Sells sandstones were investigated in eastern Crawford and western Franklin Counties, Arkansas. This area is approximately 350 square miles and extends from the northern boundary of T12N to the southern boundary of T9N. On the west, the area includes all of R29W and extends eastward to include the western half of R27W.

STRATIGRAPHIC SUCCESSION

The stratigraphic succession studied extends from the top of the Kessler Limestone to the top of the Sells sandstone unit (Fig. 1). This interval contains seven laterally persistent sandstone units bounded by equally persistent shale units. The Cecil sandstone is the third major sandstone unit above the Kessler Limestone, and the Sells sandstone is the seventh major sandstone unit above the Kessler Limestone.

CECIL SANDSTONE UNIT

The Cecil sandstone unit is the lowermost sandstone of the Cecil series and is bounded both above and below by shale units (Fig. 1). This sandstone is correlated to the basal Atoka sandstone of Washington County, Arkansas.

An isopach map (Fig. 2) of the Cecil depicts a blanket sandstone averaging 120 feet in thickness. This body of sand thins gradually northward and abruptly eastward.

The Cecil unit is characterized by a semi-inverted "Christmas tree" log signature which is illustrated in Figure 1. This log signature is suggestive of an upward increase in textural maturity, bedding thicknesses, and grain size of the sediments involved. The log signature of the Cecil unit suggests a gradational base, but not as gradational as one would expect from a delta front succession of sediments. The semi-inverted "Christmas tree" log signature has been interpreted as progradation of coastal barrier sands over a thin sequence of prodelta silts and shelf muds.

An isopach map of the Cecil sandstone unit in western Crawford County shows a broad southeast trending belt of thickened strata. This thickened belt is on trend with approximately 200 feet of Cecil sand located south and southwest of the area investigated. This succession possesses an inverted "Christmas tree" log signature, suggestive of a delta front succession.

Haley and Hendricks (1972) show the western and southern limits of the Cecil sandstone unit. The western limit occurs just east of the Oklahoma-Arkansas border. The southern or basinward limit is a few miles south of the southern boundary of T8N.

The Cecil sandstone has been interpreted as forming in a wave dominated basin as a cupsate destructional delta. The southeast thickened trend in western Crawford County represents an area of occupation by distributary channels which fed sediments to distributary mouth bars in township 8N, ranges 30W and 29W. The absence of Cecil sandstone in the vicinity of the Oklahoma-Arkansas border suggests that longshore drift was from the west to the east. Reworked sand was carried northward from distributary mouth bars in the south and later deposited on the eastern flank of the delta as coastal barrier sands. The delta flank is represented by the blanket accumulation of sand depicted in Figure 2.

SELLS SANDSTONE UNIT

The Sells sandstone unit is the uppermost sandstone of the Cecil series and is bounded above and below by laterally extensive shale units (Fig. 1). This sandstone unit is correlated to the uppermost part of the second Atoka sandstone of Washington, County.

An isopach map (Fig. 3) of the Sells sandstone shows a bifurcating thickening trend to the southwest and southeast. These thickened areas of strata are bounded laterally by areas of thinner strata.

The Sells sandstone unit is characterized by two types of well log signatures. The "Christmas tree" log signature illustrated in Figure 1 occurs on the thickened trends of strata shown in Figure 3. This log signature with its abrupt base and diminished response of the gamma ray and resistivity curve is suggestive of channels cut into previously deposited sediments with an accompanying decrease in textural maturity, bedding thickness, and the grain size of the sediments involved and is characteristic of a channel sandstone deposit. The area of occupation by distributary channels is exhibited on the log map of the Sells sandstone (Fig. 4). The other type of mechanical log signature shows immature sandstones interbedded with shales. This log signature (Fig. 4) occurs in the areas of thinner strata (Fig. 3) and is representative of a sandstone unit formed from crevasse splays, and reworking of the distributary mouth bar sediments into inter-distributary areas.

The occurrence of the "Christmas tree" log signature on the thickened trends suggest that the Sells sandstone accumulated as a distributary channel system with sporadic interdistributary sand deposition. Sediment transport of Sells sediments was from the north.

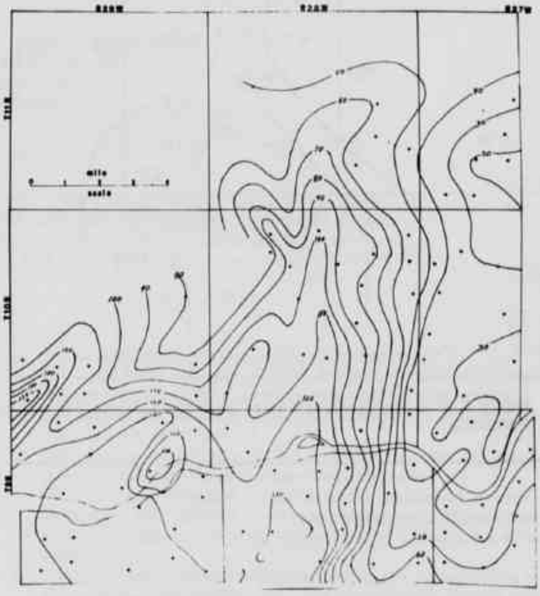

Figure 2. Isopach map of the Cecil sandstone unit, Atoka Formation. Contour interval is 10 feet.

SUMMARY

The Cecil sandstone unit accumulated in a wave dominated basin as a cupsate destructional delta. Sand reworked by marine processes was distributed to coastal barrier sands on the delta flank. The Sells sandstone unit was deposited as a distributary channel system which bifurcates to the southwest and southeast. These distributary channels fed a Sells delta farther to the south.

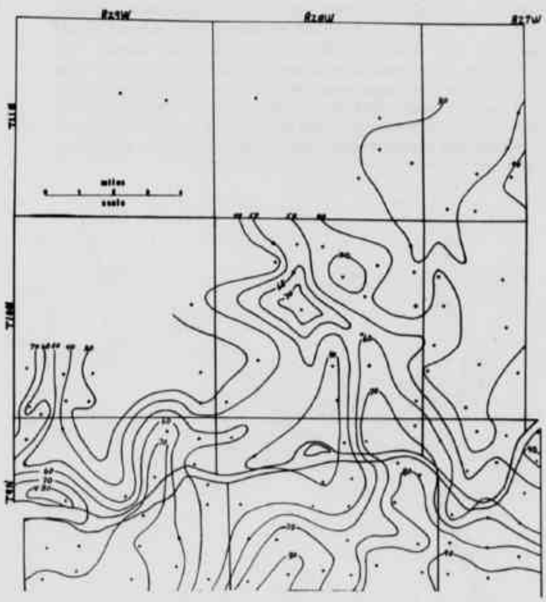

Figure 3. Isopach map of the Sells sandstone unit, Atoka Formation. Contour interval is 10 feet.

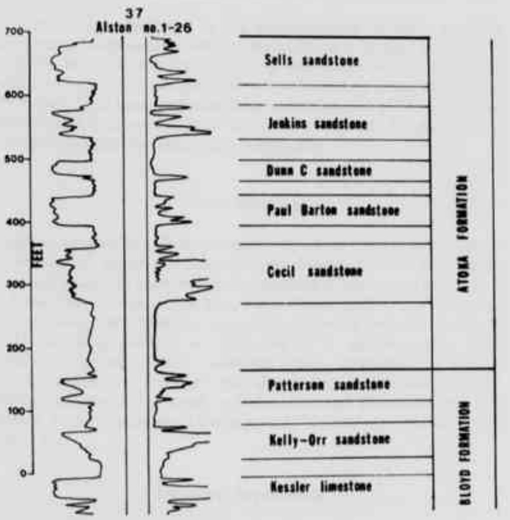

Figure 1. Alston no. 1-26 illustrating typical expression of Atoka sandstone units and their nomenclature.

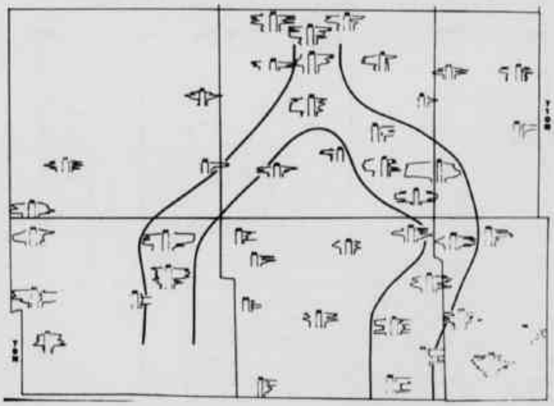

Figure 4. Well log signature map of the Sells sandstone unit, Atoka Formation.

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The Concentration of Radionuclides in Dardanelle Lake, Arkansas

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ABSTRACT

Concentrations of the nuclides ^{90}Sr-^{90}Y, ^{144}Ce-^{144}Pr, ^{137}Cs, ^{58}Co, ^{110m}Ag, ^{141}Ce and ^{89}Sr have been measured monthly since November, 1975. The results from the period September, 1976, to August, 1977, depend on the relative intensities of the sources of the radionuclides; emissions from Nuclear I, the Chinese nuclear tests of Fall, 1976, and fallout from older atmospheric tests.

INTRODUCTION

Very low concentrations of some commonly produced radionuclides have been measured in the Dardanelle Lake area of the Arkansas River near the Arkansas Nuclear I Power Station operated by Arkansas Power and Light Company. The main thrust of this program was to determine the changes in the concentrations of the radionuclides, as a result of reactor operation, as a function of their distance from the source. The radionuclides whose concentrations were measured were ^{137}Cs, $^{144}Ce-^{144}Pr$, $^{90}Sr-^{90}Y$, ^{58}Co, and ^{110m}Ag. After the Chinese nuclear test explosions in the autumn of 1976, ^{89}Sr and ^{141}Ce were added to the list. A gross beta activity measurement was also made for each sample.

The radioactive effluent from Arkansas Nuclear I consists of a low level, continuous discharge and occasional planned releases of high activity waste that seemed to contain only ^{137}Cs and ^{58}Co in relatively large quantities along with small quantities of ^{110m}Ag, $^{90}Sr-^{90}Y$, ^{134}Cs and ^{60}Co. Only in these planned releases were the latter two nuclides observed.

Samples taken after a planned release provided some information about short-term and long-term mixing in Lake Dardanelle.

MATERIAL AND METHODS

To assure high sensitivity in the determination of these nuclides, radiochemical separations were performed on a sample of approximately 20 liters in volume. Counting was done with a low-background, anti-coincidence, gas-flow proportional counter. In the case of ^{58}Co and ^{137}Cs concentrations of greater than 0.5 pCi/1, low background NaI(T1) detectors and multichannel pulse height analysis were used for identification and confirmation.

Water Sampling

Samples varying in volume from 18 - 22 liters were taken from the surface at four points each month (see Figure 1) from November, 1975, to August, 1977, except during periods of inclement weather. It was found that, in the outlet bay, water discharged from the cooling tower remained in a surface layer approximately two feet in depth. For all sampling periods of 1976 and 1977, samples were taken monthly at Stations 1, 2 and 4 and bimonthly, alternately, at Stations 3 and 6. Sampling at Station 6 was discontinued after March, 1977. Alternate stations were used in November and December of 1975 (Stations 5 and 7 were used instead of 1, 21 instead of 3, and 16 instead of 2).

Chemical Separations

1. An aliquot of 2.00 liters of river water was taken to analyze for ^{110m}Ag. An aliquot of 250 - 500 ml was taken to prepare the gross beta sample.
2. The remaining sample was acidified and carriers of Cs^+, Co^{2+}, Sr^{2+} and Ce^{3+} were added. The sample was filtered through Whatman 42 paper after a settling period of two to seven days.
3. The sample was passed through a column of 100 g of Dowex-50 X8 at the rate of ~1 liter/hr.
4. The column was eluted with 500 ml of 6M HC1 and 200 ml of water. The eluate was then evaporated to dryness.
5. The Ce^{3+} was separated as $Ce(OH)_3$ and purified by solvent extraction. The purified Ce^{3+} was precipitated, filtered and counted as the oxalate after the method of Glendennin et al (1955).
6. The Co^{2+} was separated as CoS and purified by precipitation as $K_3Co(NO_2)_6$. The purified Co^{2+} was precipitated, filtered and counted as CoS after the method of Burgus (1961).
7. The Sr^{2+} was separated as $SrCO_3$ and purified by precipitation of $Sr(NO_3)_2$ from fuming HNO_3 after the method of Hodges as summarized by Beck (1975).
8. The Cs^+ was separated by coprecipitation with ammonium phosphomolybdate, purified by precipitation of $CsC1O_4$ from absolute ethanol solution after the method of Kahn et al (1957). The Cs fraction was counted in this form.
9. Ag^+ carrier was added to the 2.00 1 aliquot. The Ag^+ was separated as AgC1. The precipitate was dissolved in conc. NH_3 and the $Ag(NH_3)_2{}^+$ solution was scavenged by $Fe(OH)_3$. The purified Ag^+ was precipitated, filtered and counted as AgC1.
10. The 250 ml aliquot was filtered and evaporated to dryness. The unfiltrable solids were slurried and quantitatively transferred to

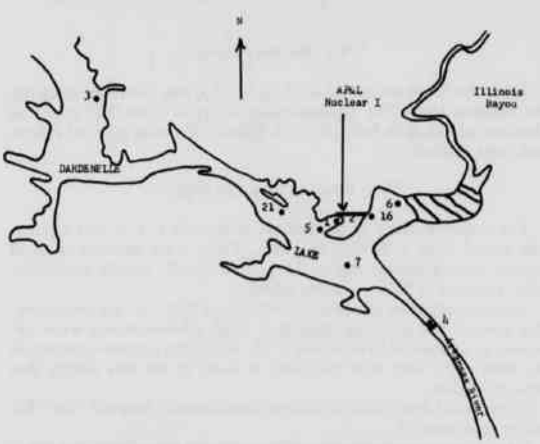

Figure 1. Sampling Stations, Dardanelle Lake Impoundment Area of the Arkansas River, Arkansas

aluminum planchets. After they were dried without baking, they were stored in a dessicator until they were counted after the method of Krieger (1975).

Counting Systems and Procedures

All the samples, except the gross beta samples, were wrapped in Mylar film with a thickness of 1-4 mg/cm^2. These samples were counted in either a Tracerlab Omni-Guard system with a 1" sample detector (G=0.209) or a Tennelec System equipped with a 2¼" Beckman anticoincidence detector (G=0.283).

The Cs and Co fractions from June and July, 1976, were also counted with a 3" x 3" NaI(T1) detector housed in a 4" (minimum) lead shield.

Analysis of Data

All beta and X-ray (in the case of ^{58}Co only) counting data were corrected for systematic errors, i.e. the geometry of the detector, backscattering, absorption of radiation by sample cover and detector window, and self-absorption and self-scattering. Correction factors for the last two errors are from Nervik and Stevenson (1952).

Chronology of Significant Events

1. June 21, 1976 - planned release of stored cooling water into Dardanelle Lake as stations were being sampled.
2. September 26, October 17, and November 17, 1976 - Chinese test nuclear devices in the atmosphere.
3. January 27, 1977 - Nuclear I shut down for refueling.
4. March 26, 1977 - refueling completed. Start-up followed closely.

RESULTS AND DISCUSSION

^{144}Ce - ^{144}Pr - Fission Products

The concentration of this pair varied only slightly, from 0.00 to 0.05 pCi/1 for the period from 11/75 to 3/77, except for the two months following the Chinese nuclear tests.

Figure 2 summarizes the concentration data for this pair from 12/76 to 8/77. Immediately before and during refueling the concentration was quite low. After resumption of operation, the concentration rose to 0.05 - 0.15 pCi/1, higher than before refueling. There is little doubt that this increase was due entirely to reactor operation.

^{141}Ce - Fission Product

This short-lived radionuclide ($T_{1/2}$ = 33 d) was produced solely by the Chinese tests. The concentration dropped from 0.15 pCi/1 in October to less than 0.05 pCi/1 in March. A spring peak of fallout was quite evident.

^{58}Co - Neutron Reaction Product

The concentrations of this nuclide at Stations 1, 2, 3, and 4 generally varied from 0.00 to 0.10 pCi/1. There were isolated cases of higher concentrations (up to 0.8 pCi/1). Small, usually unmeasurable, amounts of ^{60}Co were also released.

Immediately after the planned release of 6/21/76, the concentration rose to 4.3 pCi/1 at Station 1. High concentrations were observed at all stations in 6/76 and 7/76, indicating extensive mixing in the lake and a very slow turnover of water in the lake during that drought period.

It was found from the 6/76 sample from Station 1 that the ^{58}Co/^{60}Co was greater than 10.

One of the most interesting and inexplicable sets of data was the concentration data for ^{58}Co at Station 6. In 12/75, the concentration was found to be an unusually high 0.88 pCi/1. The concentration in each sampling period thereafter was lower than in the preceding period. The concentration fell off monotonically with a half-life of 71 days, which is the half-life of this radionuclide.

The only explanation of this coincidence is not readily acceptable. One must conclude that the ^{58}Co contamination at this station remained undiluted by the waters of the Illinois Bayou and did not move with the current. The probability of this is quite small, but no alternative explanation presents itself.

^{110m}Ag - Neutron Reaction Product

The concentration of this nuclide was erratic but generally stayed between 0.00 and 0.40 pCi/1. In late 1975, though, levels up to 1.6 pCi/1 were observed. Since then, only on 6/21/76 has the level been abnormally high (1.2 pCi/1).

^{89}Sr - Fission Product

The trends in the concentration of this nuclide are the same as those seen in the ^{141}Ce data. ^{89}Sr is also a short-lived nuclide ($T_{1/2}$ = 53 d). Only at Station 2 in April, July and August, 1977 and at Station 1 in August were levels of ^{89}Sr anomalously high. At these times and locations the concentrations were higher than in the months immediately following the bomb tests.

^{90}Sr - ^{90}Y - Fission Products

In 1975 and early 1976, the concentration of this pair varied only slightly, from 0.6 - 0.8 pCi/1. Station 1 showed an unusually high concentration on 6/21/76 as expected.

After the Chinese tests, the levels at all stations rose to 1.1 - 1.2 pCi/1. The concentration dropped to very low levels (0.4 - 0.6 pCi/1) during refueling (see Figure 3).

After operation was recommenced, the concentration of the pair became very erratic, particularly at Stations 2 and 3 (the upstream stations) during the spring and summer, rising as high as 1.73 pCi/1. By August, concentrations at all stations had returned to the neighborhood of a more normal 0.9 pCi/1.

^{137}Cs - Fission Product

This nuclide was the most common in releases, planned or unplanned. Concentrations generally ran from 0.00 to 0.30 pCi/1.

During the release of 6/21/76, the concentration rose to 33 pCi/1 at Station 1. It is interesting to note that even before the release was finished, high levels of ^{137}Cs had already accumulated at every station. This effect was least noticeable at Station 2. High levels were observed at all stations in July and August, 1976. Assuming that there were no more releases in these two months, it can be assumed that there was a very slow turnover of the water in Lake Dardanelle during this period.

It was also found that the dilution of the released ^{137}Cs as it moved down river was not as great as expected. At the dam, Station 4, the concentration was still 2.4 pCi/1, only a 14-fold dilution. The same effect was noticed in the dilution of ^{58}Co. In the period before the next sampling was done, thorough mixing of the ^{137}Cs over the whole lake had taken place. In December, 1976, the concentration rose to 0.84 pCi/1. This may have been the remnant of a release in the preceding month.

Unusually high levels of ^{137}Cs were observed at Station 2 in April, July and August, 1977, somewhat paralleling the behavior of ^{90}Sr - ^{90}Y.

Gross Beta Activity

Gross beta activity consisted of three components; (1) fallout carried from upstream, (2) natural radioactivity (^{232}Th, ^{40}K, ^{235}U and

^{238}U) carried as unfiltrable solids and (3) release from Arkansas I. Many of the trends mentioned above are masked by components (1) and (2). A complete discussion of gross beta activity data may be found in Chittenden (1978).

Table 1 lists the maximum permissible concentrations of the various nuclides discussed in this work. It can be seen that the waterborne emissions from Nuclear I are very low level in all cases.

Only $^{90}Sr - ^{90}Y$ stays near 1 pCi/1. Although the level of this nuclide is <1% of the allowable level, the increase during 1977 is cause for concern. If these unusually high levels had occurred at all stations, abnormally high fallout could have been assumed to be the cause. It is unusual, though, that the high levels should occur only upstream from the reactor. One must resort to rather unusual mechanisms to attempt an explanation of these anomalies. Upstream currents have been observed in Lake Dardanelle. These caused the good mixing observed with ^{137}Cs and ^{58}Co in 6/76. But high levels of $^{90}Sr - ^{90}Y$ were not observed at Station 1 which should be the starting point for any liquid effluent. An alternative would be the release of volatile precursors into the atmosphere. Both ^{89}Sr and ^{90}Sr have krypton precursors of short half-life. Once they are released into the atmosphere, they and their daughters could drift up river carried by the wind where they eventually would precipitate out of the atmosphere, but not equally over all stations. Neither of these explanations is wholly satisfactory.

It is significant, though, that unusually high levels of a number of nuclides were found in Dardanelle Lake water immediately upon start up of Nuclear I after refueling. The correlation of the $^{90}Sr - ^{90}Y$ data with that of $^{144}Ce - ^{144}Pr$, ^{89}Sr and ^{137}Cs definitely hints at a containment problem immediately after start up in March, 1977. However, the data of August, 1977, indicate that the problem may have been only temporary.

ACKNOWLEDGEMENTS

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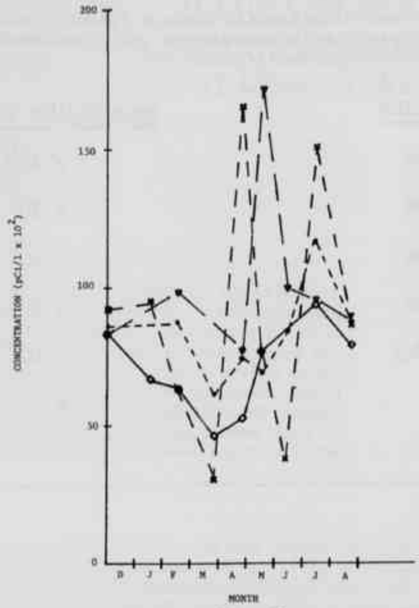

Figure 3. Concentration of $^{90}Sr - ^{90}Y$: 12/76 - 8/77

Station #1 · Station #2 · Station #3 · Station #4

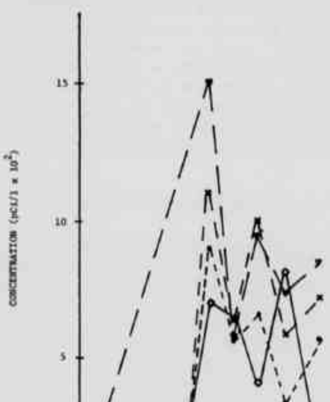

Figure 2. Concentration of $^{144}Ce - ^{144}Pr$: 12/76 - 8/77

Station #1 · Station #2 · Station #3 · Station #4

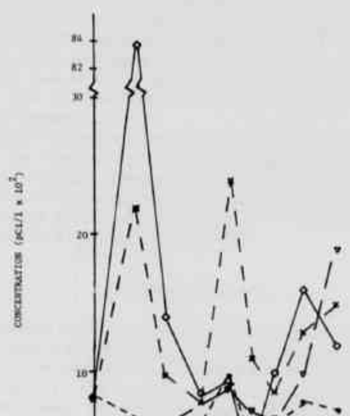

Figure 4. Concentration of ^{137}Cs: 12/76 - 8/77

Station #1 · Station #2 · Station #3 · Station #4

Table 1. Concentration Limits for Release of Radioactive Material in Liquid Effluent to an Uncontrolled Area (pCi/1) established by the Arkansas State Department of Health (1974).

NUCLIDE	PERMISSIBLE LEVEL
^{144}Ce	1×10^4
^{141}Ce	9×10^4
^{137}Cs	2×10^4
^{58m}Co	3×10^6
^{110m}Ag	3×10^4
^{89}Sr	3×10^3
^{90}Sr	3×10^2

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Geometry and Depositional Systems of the Orr and Patterson Sands, Bloyd Formation (Pennsylvanian), Eastern Franklin and Western Johnson Counties, Arkansas

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ABSTRACT

The Orr and Patterson sandstones occur in the Trace Creek Shale Member, Bloyd Formation, in surface exposures on the northern Arkansas structural platform. The Orr sandstone exhibits regional thickening trends to the south and southeast into the Arkoma Basin as shown by isolith maps for the area studied. The depositional environment that formed this sandstone comprised fluvial or deltaic channels feeding a destructive delta system to the southeast. The Patterson sandstone lies stratigraphically above the Orr sandstone, and is confined essentially to Franklin and Johnson counties. It is poorly developed or not present in Washington and western Crawford Counties. The Patterson occurs as a sand build-up formed by a lobate constructive delta system in the north of the area studied but thins to the south.

INTRODUCTION

The major structural elements in northwest Arkansas are the Ozark Dome, the northern Arkansas structural platform, and the Arkoma Basin. The northern Arkansas structural platform is a stable cratonic shelf that has undergone slight structural deformation. Strata on the platform have a slight regional dip southward toward the Arkoma Basin. The structural character of the Arkoma Basin is that of an east-trending trough bounded to the north by normal faults. Basinal strata are folded into anticlines and synclines. The structural deformation in the basin is much greater than that of the platform and increases in intensity southward.

The regional stratigraphy of northwestern Arkansas includes pre-Atoka carbonates, shales and minor sandstones on the platform north of the Boston Mountains. Both the Boston Mountains and the Arkoma Basin have pre-Atoka carbonates, shales and minor sandstones and Atoka sandstones and shales. The Atoka clastics are the predominant stratigraphic sequence in both the basin and the Boston Mountains. The sedimentary sequence on the platform is approximately 4,000 feet thick and increases in thickness southward to over 20,000 feet in the Arkoma Basin (Branan, C. B., Jr., 1968, Am. Assoc. Petroleum Geologists Memoir 9, v. 2:1658-1667).

METHODS AND MATERIALS

The data base used for this study was 108 mechanical logs obtained from wells drilled in search of natural gas in the Arkoma Basin of eastern Franklin and western Johnson Counties. Data were also obtained from two surface sections measured along the southern divide of the Boston Mountains, north of the Cass fault zone. The mechanical logs (Figure 1) were used to construct isolith maps and log signature maps. The surface sections were used to make surface to subsurface correlations and determinations of lithic characteristics of the sandstone units. From the isolith maps, log signature maps and the surface sections, interpretations were made for the depositional systems of the Orr and Patterson sandstones.

RESULTS AND DISCUSSION

Orr Sandstone

The Orr sandstone is the lowermost sandstone unit in the Trace Creek Shale Member of the Bloyd Formation. The Trace Creek Member overlies the Kessler Limestone Member of the Bloyd Formation and underlies the basal sandstone unit of the Atoka Formation. The Orr is present throughout eastern Franklin and western Johnson Counties, Arkansas, in both surface exposures and in the subsurface. It ranges in thickness from 10 feet in northern Franklin County to 160 feet in southwestern Johnson County (T9N,R25W). In surface exposures the Orr locally contains a basal shale pebble conglomerate and is best developed in northeastern Johnson County.

An isolith map of the Orr (Figure 2) in eastern Franklin and western Johnson Counties reveals a blanket sand with a regional thickening to the southeast. Superimposed upon this regional trend are belts of thicker sand accumulation that trend southeast and south. Log signatures associated with these trends in northwestern Johnson and northeastern Franklin Counties suggest abrupt bases with abrupt tops probably formed by fluvial channel deposits. In southwestern Johnson County, the Orr sand thickness is greatest, and log signatures have both gradational tops and bottoms suggesting deltaic distributary channel deposits. Away from these thickening trends, the Orr is poorly developed with shale. The signatures have gradational bases and abrupt or gradational tops indicating interbedded sand and shale deposited by interchannel or interdistributary depositional environments.

The depositional system operating during the deposition of the Orr sandstone was that of a wave dominated high destructive delta. The types of sand deposits present in eastern Franklin and western Johnson Counties are fluvial channel, distributary channel, and delta plain deposits. These depositional environments were supplying sediment to a high destructive delta to the southeast.

Patterson Sandstone

The Patterson sandstone is the upper sand unit in the Trace Creek Shale Member of the Bloyd Formation. It is separated from the Orr sandstone below and the basal Atoka sandstone above by intervals of shale (Figure 1). The Patterson is absent or poorly developed west of Franklin County. In surface exposures in northern Franklin and northern Johnson Counties the Patterson has a gradational base of alternating thin layers of sandstone and shale and is capped by a massive bedded, fossil fragment-bearing sandstone. The Patterson ranges in thickness from 30 feet to 110 feet in eastern Franklin and western Johnson Counties. The thickest and best sand development occurs in the northeast part of central Franklin County.

An isolith map of the Patterson (Figure 3) in eastern Franklin and western Johnson Counties indicates that it is a blanket sand that has a regional decrease in sand content to the south. Superimposed upon the regional trend are zones of thicker sand accumulation. These zones extend from a common zone of greatest sand thickness in the north that bifurcates to the south and southeast with decreased sand content to the south. Log signatures associated with these trends suggest a basal unit of alternating sand and shale in the northern part of the area capped by a massive sand unit. To the south the upper massive sandstone unit disappears near the Arkansas River. Away from these thickness trends the log signatures suggest alternating units of sand and shale.

The upper massive unit of the Patterson in the north represents distributary mouth bar and distributary channel deposits. The interbedded sand and shale sequences in the southern part of the area are delta front deposits overlying prodelta shales. The off-trend signatures are interdistributary-crevasse deposits overlying delta front sands.

The depositional system active during deposition of the Patterson sandstone was a river-dominated, constructive lobate delta. The depositional environments active within this system in eastern Franklin and western Johnson Counties were prodelta, delta front, distributary channel, distributary mouth bars, and interdistributary environments.

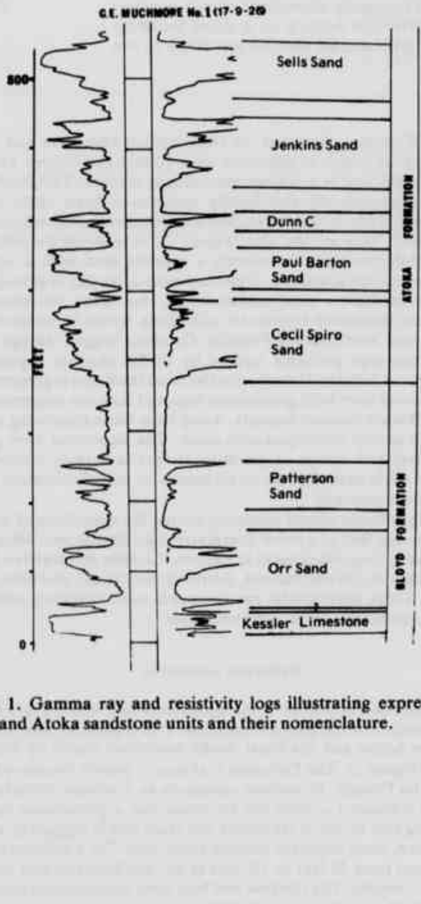

Figure 1. Gamma ray and resistivity logs illustrating expression of Bloyd and Atoka sandstone units and their nomenclature.

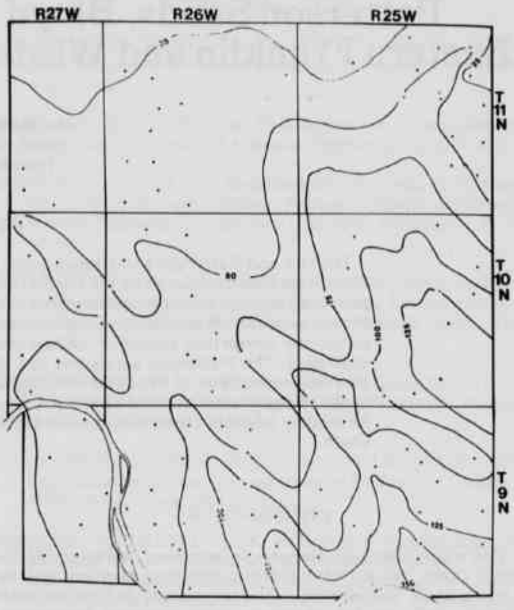

Figure 2. Isolith map of the Orr Sandstone contour interval is 25 feet.

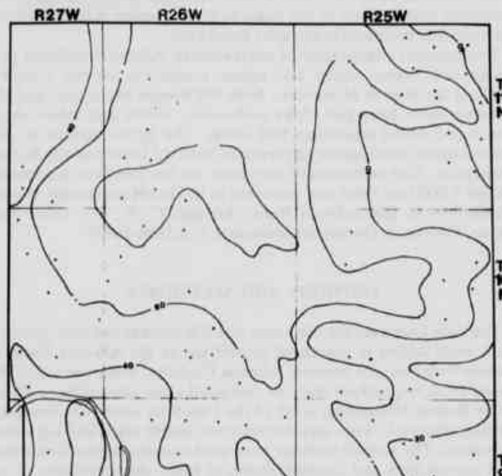

Figure 3. Isolith map of the Patterson Sandstone contour interval is 20 feet.

Ultraviolet Light Reactivation of Gamma Ray-Induced Lethal Damage in Vertebrate Cells*

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ABSTRACT

A comparison was made of the extent of UVR of gamma ray-induced lethal damage (mitigation of gamma ray-induced lethal effects by appropriate administration of low UV doses) in fish, amphibian, reptile and mammalian tissue culture cell lines. A significant level of UVR was detected in the non-mammalian lines, but the mammalian cells appeared to have lost this ability. Associated mitotic index data is interpreted as supporting the notion that low UV doses, appropriately administered, may aid repair processes in some cells (indirectly) by hindering the antagonistic metabolic processes which convert gamma ray-induced lesions to a non-reversible state.

INTRODUCTION

Ultraviolet light reactivation (UVR) has been observed in many microorganisms. When UV-inactivated phage are allowed to infect appropriate host cell bacteria and these infected systems receive appropriate UV exposures, significant increases in phage survival are observed. This UVR of phage has been observed repeatedly (Weigle, 1953; Rupert and Harm, 1966). Elkind and Sutton (1959) and Calkins and Todd (1968) have described UVR of X-ray induced lethal damage in yeast. Calkins and Griggs (1969) observed a rather marked degree of UVR of x-ray induced lethal damage in protozoa. This report deals primarily with an attempt to determine whether UVR of ionizing radiation-induced lethal damage extends to mammalian and other vertebrate cell cultures.

MATERIALS AND METHODS

The two mammalian tissue culture lines used were the H3 HeLa human cancer line and V79 hamster *(Cricetulus griseus)* line, obtained from Dr. Joel Bedford of Colorado State University. Both lines were routinely maintained in closed tissue culture flasks at 37°C in F10 medium supplemented with 10 percent fetal calf serum and buffered with HEPES. Three non-mammalian vertebrate cell lines, derived from lines furnished by Dr. James Regan of Oak Ridge National Lab were used: the GFI fish line derived from a *Haemulon scuirus* line, the A8W243 amphibian line derived from a *Xenopus laevis* line, and the THI reptile line derived from a *Terrapene carolina* line. These non-mammalian lines were routinely maintained in essentially the same manner as has been described previously for A8W243 cells (Griggs and Bender, 1972).

Monolayers of cells in vigorous log phase growth in plastic petri plates were used in all experiments. Gamma ray was administered at a dose rate of 40 rads/minute by a custom designed Mark IV Cesium 137 irradiator. This machine is designed so that the same monolayer samples prepared for UV exposure can also be conveniently exposed to gamma ray. The techniques employed in UV exposures, incubation, single cell isolations, colony assays, and other aspects of dose-survival determinations have been previously described (Griggs and Bender, 1972; Orr and Griggs, 1976).

The UVR experiments for each cell line involved the following. The gamma ray dose-survival relationship was determined to enhance selection of an appropriate gamma ray dose level for the UVR detection test (i.e., a gamma ray dose level at which any significant change in cell survival due to subsequent administration of low UV doses could be detected). Medium was removed from a series of plates containing the desired monolayers and replaced with a thin layer (0.5 mm in depth) of balanced salt solution. Immediately following administration of the same appropriate gamma ray dose to all members of the series, each member was exposed to a different dose of UV in the range 0 to 20 ergs/mm^2. These "doubly exposed" monolayers were then converted to single cell suspensions and the remainder of the experiment carried out essentially as described by Griggs and Bender (1972).

*Research supported in part by National Cancer Institute Grant CA-18809-2.

RESULTS AND DISCUSSION

The shapes of the gamma ray dose-survival responses in Figures 1 and 2 indicate that dose levels which result in surviving fractions between about 0.1 and 0.6 would be appropriate levels at which to test for UVR ability in all five cell lines. Thus, the 0.5 survival point was used. Consideration of the progression of radiation events (up the evolutionary scale) from fish to human cells in Figures 1 and 2 indicates a definite decrease in gamma ray resistance. The LD50 (dose that is lethal to 50 percent of the cells) ranges from about 1000 rads in the fish line to near 500 rads in the human cells. It is interesting that UVR ability seems to roughly parallel the gamma ray resistance in that a marked degree is present in fish and amphibian cells, less in reptile cells and little, if any, in mammalian cells.

The mechanism of UVR has not been adequately described. Ono and Shimazu (1966) suggest that UVR results from a form of enzyme induction. Kneser et al (1965) and Calkins and Todd (1968) have published data which they interpret as supporting the notion that UVR results from induction of an enzyme repair system by appropriate UV administration. These suggestions have led to little elucidation of UVR since techniques for exploring the nature and extent of such intracellular mechanisms have not been developed.

The experimental results depicted in Figure 3 suggest an alternative, and perhaps simpler, mechanism for UVR. Comparison of the data clearly indicate that a gamma ray dose of 600 rads induces a drop in mitotic index in the A8W243 cells that persists for about 20 hours in log phase A8W243 cells. When a low dose of UV is administered in conjunction with the gamma ray, cell progression is practically stopped (arrows pointing downward) for about 12 hours and the mitotic index is drastically decreased for more than 32 hours. However, the same combination of exposures does not induce such a pronounced decrease in mitotic index in the V79 cell line. Intracellular mechanisms capable of repairing radiation-induced, potentially lethal damage have been detected in vertebrate cells (Elkind and Whitmore, 1967; Griggs and Bender, 1972). It has also been shown that low temperatures and a number of chemical agents can, under proper circumstances, alter the rate of metabolic activities in such a manner as to enhance repair of radiation damage (Elkind and Whitmore, 1967). These facts, coupled with the data from Figure 3, suggest that appropriate administration of low UV doses to some vertebrate cells, following ionizing radiation exposures, alters metabolic activities in such a manner as to significantly delay cells in their progression through the cell cycle. This delay allows repair mechanisms more time to operate, resulting in the increased level of survival which has been called UVR.

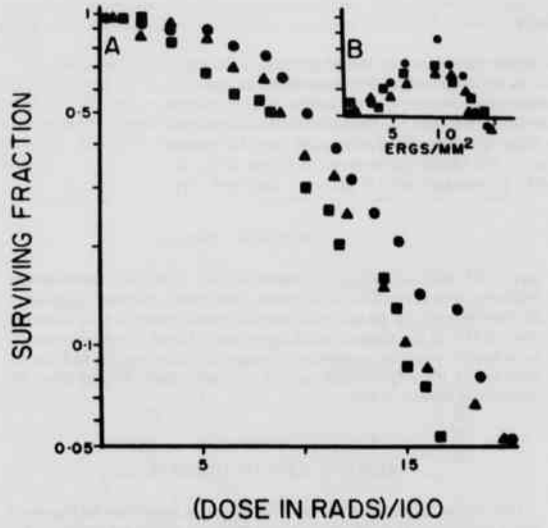

Figure 1. (A) Gamma ray survival curves; (B) Gamma ray plus UV survival curves (UVR); filled circles = GFI cells, filled triangles = A8W243 cells, filled squares = THI cells.

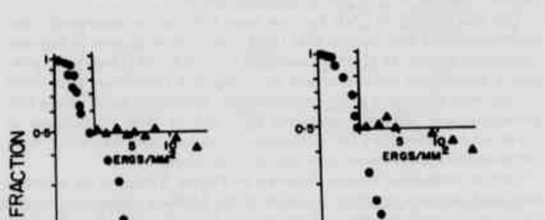

Figure 2. Gamma ray survival curves (filled circles) and gamma ray plus UV survival curves (UVR) (filled triangles) for hamster (V79) and human (HeLa) cell lines.

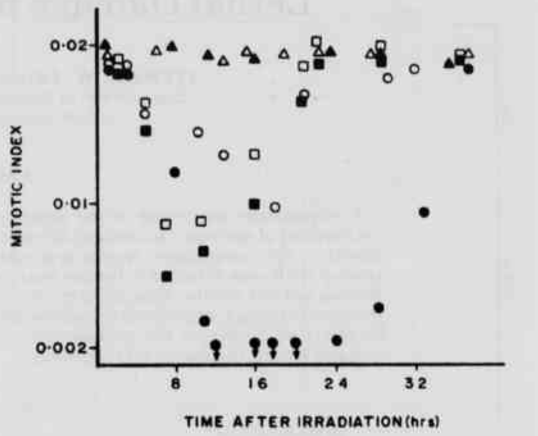

Figure 3. Radiation induced mitotic delay in log phase A8W243 (filled symbols) and V79 (open symbols) cells. Triangles = controls, squares = 600 rad gamma ray, circles = 600 rad gamma ray plus 15 ergs/mm² UV.

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Fishes of the Caddo River, Arkansas After Impoundment of DeGray Lake

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ABSTRACT

Fifty-five collections of fishes were made with small-mesh seines and electrofishing gear in the Caddo River and four of its tributaries during 1974-75. Eighty-two species representing 17 families were collected; 14 of the species had not previously been reported from the Caddo River.

INTRODUCTION

The Caddo River, flowing through the Ouachita Mountains in west central Arkansas, is a tributary of the Ouachita River (Fig. 1). Studies on the fishes of the river are limited. Meek (1891) reported that the Caddo River contained "few fish and few species," and Hubbs and Ortenburger (1929) collected only 15 species. Fruge (1971), who conducted the first extensive survey of the fishes of the Caddo River, reported a total of 72 species. Collections during the present survey expanded the species list compiled by Fruge.

The Caddo River has a watershed of approximately 1191 km^2. The drainage area is characterized by forested hills and narrow valleys. The headwaters are in an area which is predominantly Womble shale and Blakely sandstone. The river flows east-southeasterly through areas of sandstone and shale before turning southerly in an alluvial area and merging with the Ouachita River. In August 1969, 5,463 ha DeGray Lake and a 202 ha reregulating pool were impounded on the lower section of the river (Fig. 1).

The physicochemical features of the Caddo River are characteristic of Ouachita Mountain streams (J. Nix, *pers. comm.*). The water of the river contains low concentrations of dissolved solids (25-100 ppm) and is classified as a calcium-bicarbonate type. Alkalinity values range between 23 and 50 mg/1 (as $CaCO_3$). Higher than normal calcium concentrations for the rivers in this area occur in the headwaters because of the presence of limestone in the shale deposits. Dissolved oxygen remains near saturation throughout the year. Water temperatures above DeGray Lake range from 8 - 16 C (annual $\bar{X}$, 14 C). Turbidity values are relatively low, but increase markedly during periods of high runoff. Seasonal flow rates in the middle section of the river range from 3 to 254 m^3/s.

METHODS AND MATERIALS

Fifty-five fish collections were made between May 1974 and July 1975. Sixteen locations on the Caddo River and four of its tributaries (Sta. 3, 4, 10, 11, 12) were sampled (Fig. 1). Although a few areas in small tributary streams were sampled only once because of the paucity of fishes, most stations were sampled at least twice and station 15 was sampled seven times.

Collections were made with small-mesh seines and electrofishing gear. Thirty-four collections were made with two 6.4 mm mesh seines, 3.1 X 1.8 m and 6.1 X 1.8 m in size. In six of these collections, a portable 110 V generator and two hand-held electrodes were also used. The electrodes consisted of two 2.1 m fiberglass wrapped aluminum poles with a grid of copper wire soldered to a hoop of copper tubing at one end. Wires 30 m long connected to each electrode allowed the operators to cover 60 m of stream without moving the generator. Twenty-one collections were made with a 4.6 m flat-bottom aluminum boat modified for electrofishing in rivers and streams. Two removable 2.1 m fiberglass wrapped aluminum poles were mounted on each side of the bow. The electrode array on each boom consisted of two 1.5 m electrodes of 12.7 mm flexible conduit suspended 0.4 m apart. A Smith-Root Type VI Electrofisher[1] was used to control the voltage and amperage of the pulsed DC.

The specimens were preserved in 10% formalin and returned to the laboratory for identification. Taxonomic keys used in species identification were those of Buchanan (1973), Miller and Robison (1973) and Douglas (1974). Most specimens are stored at the Multi-Outlet Reservoir Studies Laboratory, Arkadelphia, Arkansas.

FISH COMMUNITY COMPOSITION

Headwater Section: The headwater section of the river (Stations 1-4), is characterized by clear, shallow, fast-flowing water and rock or gravel substrate, and by large populations of *Fundulus catenatus*, *Campostoma anomalum*, *Notropis boops*, *N. chrysocephalus*, *N. umbratilis*, and *Etheostoma radiosum*. Common centrarchids included *Lepomis megalotis* and *L. cyanellus*. *Micropterus dolomieui*, although not collected in large numbers, was the most common *Micropterus* species collected. The only madtom collected was *Noturus taylori*.

Middle Section: In this portion of the river (Stations 5-9) the pools are deeper and wider, and riffle habitat diminishes in proportion. This section of the river contained abundant populations of *Fundulus catenatus*, *Pimephales notatus*, *Notropis boops*, *N. whipplei*, *Lepomis megalotis*, *L. macrochirus*, and *Etheostoma radiosum*. *Micropterus salmoides* and *M. punctulatus* occurred in about equal numbers and were more common than *M. dolomieui*. *M. dolomieui* was the most abundant bass only at Station 5. *Ambloplites rupestris* was common in many of the clear, rocky pools. Common darters collected included *Percina caprodes*, *Etheostoma radiosum*, and *E. zonale*. *Labidesthes sicculus* was abundant in the section of

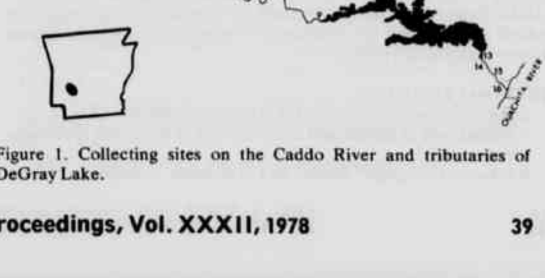

Figure 1. Collecting sites on the Caddo River and tributaries of DeGray Lake.

[1]Reference to trade names does not imply Government endorsement of commercial products.

the river near the upper portion of DeGray Lake. Migrants from the reservoir into the river in this area (Station 9) included *Dorosoma cepedianum*, *D. petenense*, *Morone chrysops*, and *Pomoxis nigromaculatus*. Although the extent of this migration is not known, we do not believe that it is extensive. Samples taken at Station 8 and upstream have showed no seasonal increases in numbers of these species. *Moxostoma erythrurum*, *M. duquesnei*, and *Hypentelium nigricans*, although not abundant, were found throughout the middle section.

Lower Section: The waters are more turbid in the lower section of the river (Stations 13-16), and there is more emergent vegetation (*Dianthera* sp.) in the shallow areas. *Fundulus olivaceus*, *Pimephales notatus*, *Notropis whipplei*, *Lepomis megalotis*, *L. macrochirus* and *Labidesthes sicculus* were common throughout this section. *Moxostoma erythrurum* and *M. duquesnei* occurred throughout the lower portion of the river and were most abundant immediately below the reregulating pool (Station 14). *Cyprinus carpio* was also abundant at this station, the only station where it occurred in large numbers. *Minytrema melanops* was collected throughout the lower portion of the river but not in large numbers. *Micropterus salmoides* and *M. punctulatus* were more abundant in the lower portion of the river, but the relative abundance was similar to that in the middle section. The most common darters collected at these stations were *Etheostoma radiosum* and *E. zonale*. However, more species of percids and cyprinids were collected in the lower portion of the river probably because of the greater diversity of habitat there than in the upstream sections. Percids collected were *Etheostoma blennioides*, *E. chlorosomum*, *E. collettei*, *E. gracile*, *E. histrio*, *E. proeliare*, *E. radiosum*, *E. stigmaeum*, *E. whipplei*, *E. zonale*, *Percina caprodes*, *P. copelandi*, and *Stizostedion vitreum*.

Cyprinids taken in the lower river were *Campostoma anomalum*, *Cyprinus carpio*, *Hybopsis x-punctata*, *Notropis atherinoides*, *N. boops*, *N. chrysocephalus*, *N. emiliae*, *N. fumeus*, *N. perpallidus*, *N. umbratilis*, *N. venustus*, *N. whipplei*, *Pimephales notatus*, *P. tenellus* and *P. vigilax*.

DISCUSSION

Seven species reported by Fruge (1971) were not collected by us: *Notropis amnis*, *N. rubellus*, *Noturus eleutherus*, *Ammocrypta vivax*, *Percina maculata*, *P. nasuta*, and *Etheostoma nigrum*. Of these, only *Notropis rubellus* and *Noturus eleutherus* were collected in sizable numbers by Fruge. We cannot explain why we failed to collect these two species. The darter species, which were not abundant are more apt to be collected with seines and possibly night collections which Fruge used more extensively than we did. Fruge collected a single specimen of *Notropis amnis*.

Fourteen species were collected that were not listed by Fruge (1971) or by earlier collections: *Ichthyomyzon gagei*, *Amia calva*, *Lepisosteus oculatus*, *Alosa chrysochloris*, *Esox niger*, *Cyprinus carpio*, *Fundulus notti*, *Carpiodes cyrpinus*, *Ictiobus cyprinellus*, *Moxostoma carinatum*, *M. poecilurum*, *Anguilla rostrata*, *Ictalurus melas*, and *Noturus gyrinus*. None of these species was common. The addition of most of these species to the list compiled by Fruge (1971) was due mainly to the efficiency of the electroshocking boat in collecting stream species.

ANNOTATED LIST OF SPECIES COLLECTED

More than 10,000 specimens representing 82 species and 17 families were collected. The following annotated list shows the species collected and a brief description of relative abundance. Arabic numerals following the common name indicate the stations at which each species was collected. Common and scientific names follow Bailey et al. (1970).

PETROMYZONTIDAE

Ichthyomyzon castaneus Girard - Chestnut lamprey - 7,8,9,14,15.
Found only in middle and lower portion of river; few specimens collected.

Ichthyomyzon gagei Hubbs and Tratuman - Southern brook lamprey - 7,8,9,15,16.
Found only in middle and lower portions of river; few specimens collected.

POLYODONTIDAE

Polyodon spathula (Walbaum) - Paddlefish - 14.
Common in the spring at the base of the reregulating dam below DeGray Lake; no specimens collected elsewhere.

LEPISOSTEIDAE

Lepisosteus oculatus (Winchell) - Spotted gar - 14,15,16.
Common in pools in lower portion of river. Not collected above DeGray Lake.

Lepisosteus osseus (Linnaeus) - Longnose gar - 8,14,15,16.
Uncommon. Two species collected in the middle section of the river and three in the lower.

AMIIDAE

Amia calva Linnaeus - Bowfin - 14.
Rare. Collected in lower portion of river below DeGray Reservoir in pool habitat.

ANGUILLIDAE

Anguilla rostrata (Lesueur) - American eel - 5,9,14,15.
Uncommon. Six specimens collected.

CLUPEIDAE

Alosa chrysochloris (Rafinesque) - Skipjack herring - 14.
Uncommon. Collected only at base of reregulating dam.

Dorosoma cepedianum (Lesueur) - Gizzard shad - 6,7,8,9,13,14, 15,16.
Common in middle and lower portions of river, especially near DeGray Lake and confluence with Ouachita River.

Dorosoma petenense (Gunther) - Threadfin shad - 9,13,14,15.
Common in portion of river near reservoir confluence.

ESOCIDAE

Esox americanus vermiculatus Lesueur - Grass pickerel - 3,14,15.
Uncommon. Two specimens collected in middle portion of river and three below DeGray Lake.

Exos niger Lesueur - Chain pickerel - 13,14,15.
Uncommon. Fourteen specimens collected in reregulating pool and below.

CYPRINIDAE

Campostoma anomalum (Rafinesque) - Stoneroller - 1,2,3,4,5,6,7, 10,11,12,15.
Found throughout the river but most abundant in the swifter water in the headwater region and in the small tributary streams of DeGray Lake (Stations 10, 11, 12).

Cyprinus carpio Linnaeus - Carp - 14,15,16.
Common in lower portion of river, especially in deep pools below reregulating dam and near confluence with Ouachita River.

Hybopsis x-punctata Hubbs and Crowe - Gravel chub - 6,7,14,15.
Although not collected in large numbers, most common in lower portion of river.

Notemigonus crysoleucas (Mitchill) - Golden shiner - 3.
Rare. Only one specimen collected.

Notropis atherinoides Rafinesque - Emerald shiner - 14,15,16.
Uncommon. Found only in pools in lower portion of river.

Notropis boops Gilbert - Bigeye shiner - 2,3,4,5,6,7,8,9,10,11,12, 13,14,15,16.
Abundant throughout the river.

Notropis chrysocephalus (Rafinesque) - Striped shiner - 1,2,3,4,5, 7,10.
Abundant in the headwater section of the river.

Notropis emiliae (Hay) - Pugnose minnow - 13,14,15,16.
Uncommon. Fourteen of 22 specimens were taken in reregulating pool (Sta. 13).

Notropis fumeus Evermann - Ribbon shiner - 15.
Rare. Only a few specimens collected in the lower portion of the river.

Notropis perpallidus Hubbs and Black - Colorless shiner - 8,14,15.
Uncommon. Most specimens collected in lower section of river.
Notropis umbratilis (Girard) - Redfin shiner - 2,3,4,5,6,9,10,11,12,13,15.
Although found throughout the river, abundant only in the headwater region.
Notropis venustus (Girard) - Blacktail shiner - 16.
Rare. Only two specimens collected near confluence with Ouachita River.
Notropis whipplei (Girard) - Steelcolor shiner - 3,4,6,7,8,9,12,14,15,16.
Common throughout the river.
Pimephales notatus (Rafinesque) - Bluntnose minnow - 3,4,5,6,7,8,9,11,12,13,14,15.
Common throughout the river, especially abundant in the middle portion.
Pimephales tenellus (Girard) - Slim minnow - 9,13.
Uncommon. Only 6 specimens collected.
Pimephales vigilax (Baird and Girard) - Bullhead minnow - 14.
Rare. One specimen collected.
Semotilus atromaculatus (Mitchill) - Creek chub - 1,2,3.
Uncommon. Found only in the clear, swift headwaters.

CATOSTOMIDAE

Carpiodes cyprinus (Lesueur) - Quillback - 14.
Rare. One specimen collected.
Erimyzon oblongus (Mitchell) - Creek chub sucker - 7,10.
Rare. Only 2 specimens collected.
Hypentelium nigricans (Lesueur) - Northern hog sucker - 1,2,5,6,7,8,9,14,15,16.
Most common in the middle and upper portion of the river in clear, swift waters.
Ictiobus cyrpinellus (Valenciennes) - Bigmouth buffalo - 14.
Rare. Only 1 specimen collected.
Minytrema melanops (Rafinesque) - Spotted sucker - 6,13,14,15,16.
Uncommon. Found mainly below DeGray Lake in the lower section of the river.
Moxostoma duquesnei (Lesueur) - Black redhorse - 5,6,9,14,16.
Common in the middle and lower portion of the river.
Moxostoma erythrurum (Rafinesque) - Golden redhorse - 5,8,9,13,14,15,16.
Common in middle and lower portions of the river, especially below reregulating pool.
Moxostoma carinatum (Cope) - River redhorse - 14,15.
Uncommon. Only 4 specimens collected, all in the lower section of river.
Moxostoma poecilurum (Jordan) - Blacktail redhorse - 14.
Rare. One specimen collected below DeGray Lake.

ICTALURIDAE

Ictalurus melas (Rafinesque) - Black bullhead - 14.
Rare. Only one specimen collected.
Ictalurus natalis (Lesueur) - Yellow bullhead - 4,5,7,9,13,15,16.
Although widely distributed, only one or two specimens were collected at each station.
Ictalurus punctatus (Rafinesque) - Channel catfish - 6,13,14,15.
Uncommon. Seven specimens collected.
Pylodictis oliveris (Rafinesque) - Flathead catfish - 5,9,15.
Uncommon. Although only three specimens were collected in the present survey, subsequent electrofishing at Station 8 revealed a larger population.
Noturus miurus Jordan - Brindled madtom - 7,14,16.
Uncommon. Only four specimens collected. The low number of all madtom species collected was probably due to gear avoidance.
Noturus nocturnus Jordan and Gilbert - Freckled madtom - 15.
Uncommon. Five specimens collected, all in the lower section of the river.
Noturus taylori Douglas - Caddo madtom - 1,3,5,7.
Ten specimens collected. Distribution limited to middle and headwater sections of the river.
Noturus gyrinus (Mitchill) - Tadpole madtom - 15.
One specimen collected in the river. Other specimens collected in DeGray Lake. Distribution probably limited to the lake and river below.

APHREDODERIDAE

Aphredoderus sayanus (Gilliams) - Pirate perch - 13,15.
Rare. Only two specimens collected, both in the lower river. More common in reservoir collections that were not part of this survey.

CYPRINODONTIDAE

Fundulus catenatus (Storer) - Northern studfish - 1,2,3,4,5,6,7,10,12,15.
Found throughout the river but abundant in the headwaters and middle portion of the river above DeGray Lake.
Fundulus notatus (Rafinesque) - Blackstripe topminnow - 15.
Rare. Distribution apparently limited to lower section of river.
Fundulus notti (Agassiz) - Starhead topminnow - 15.
Rare. Only one specimen collected in a small overflow pond near river.
Fundulus olivaceus (Storer) - Blackspotted topminnow - 3,4,5,6,7,8,9,10,12,13,14,15,16.
Common throughout the river.

POECILIIDAE

Gambusia affinis (Baird and Girard) - Mosquitofish - 4,7,15.
Common only in the lower section of the river in two small overflow ponds.

ATHERINIDAE

Labidesthes sicculus (Cope) - Brook silverside - 3,4,5,6,7,8,9,12,13,14,15,16.
Found throughout the river and abundant in the lower section.

PERCICHTHYIDAE

Morone chrysops (Rafinesque) - White Bass - 9,13.
Uncommon. One specimen collected in reregulating pool and several at the upper end of DeGray Lake at river confluence during spring spawning migration.

CENTRARCHIDAE

Ambloplites rupestris (Rafinesque) - Rock bass - 4,6,7,8,9,15.
More common in the clear water above DeGray Lake than in the more turbid water below.
Elassoma zonatum Jordan - Banded pygmy sunfish - 15.
Rare. Two specimens collected in an isolated overflow pond near main river channel.
Lepomis cyanellus Rafinesque - Green sunfish - 3,4,6,7,8,9,10,11,12,13,14,15,16.
Found throughout the river but not abundant.
Lepomis gulosus (Cuvier) Warmouth - 8,9,13,14.
Uncommon. Most collected in reregulating pool and near confluence of river and reservoir.
Lepomis humilis (Girard) - Orangespotted sunfish - 13.
Rare. Only one specimen collected.
Lepomis macrochirus Rafinesque - Bluegill - 1,2,3,4,5,6,7,8,9,13,14,15,16.
Abundant throughout the river, especially in the lower section.
Lepomis megalotis (Rafinesque) - Longear sunfish - 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16.
The most abundant centrarchid collected.
Lepomis microlophus (Gunther) Redear sunfish - 7,8,9,13,14,15.
Found in the middle and lower section of the river; most common near DeGray Lake.
Lepomis punctatus (Valenciennes) - Spotted sunfish.
Rare. One specimen collected from DeGray Lake. Although we collected this species from the lake, we feel that it is present in the river as reported by Fruge (1971).
Micropterus dolomieui Lacepede - Smallmouth bass - 1,3,5,6,7,8,9.
Collected only in the headwater and middle section of the river. Least abundant of the three *Micropterus* species collected.
Micropterus punctulatus (Rafinesque) - Spotted bass - 6,7,8,9,10,13,14,15,16.
Common through the middle and lower section of the river.
Micropterus salmoides (Lacepede) - Largemouth bass - 3,5,6,7,8,9,10,11,13,14,15,16.
Most abundant of the *Micropterus* species collected.

Pomoxis annularis Rafinesque - White crappie - 6,8,9,14,16.
Uncommon. Only ten specimens collected.

Pomoxis nigromaculatus (Lesueur) - Black crappie - 6,8,9,14,16.
Found throughout the middle and lower portions of the river but not in large numbers.

PERCIDAE

Etheostoma blennioides Rafinesque - Greenside darter - 1,3,8,15.
Widely distributed. The low numbers collected probably indicate gear selectivity (electroshocker). Fruge (1971) stated that this species was common, especially in swiftly running water with large rocks.

Etheostoma chlorosomum (Hay) - Bluntnose darter - 13,16.
Rare. Two specimens collected in lower section of river.

Etheostoma collettei Birdsong and Knapp - Creole darter - 6,7,14, 15,16.
Common in lower section of river.

Etheostoma gracile (Girard) - Slough darter - 15.
Rare. Only one specimen collected.

Etheostoma histrio Jordan and Gilbert - Harlequin darter - 14,15.
Not common. Four specimens collected in lower section of river.

Etheostoma pallididorsum Distler and Metcalf - Paleback darter - 1.
Only one specimen collected, in the extreme headwater region. Fruge (1971) stated that the paleback darter was common in the sloughs and backwaters of the upper headwaters.

Etheostoma proeliare (Hay) - Cypress darter - 15.
Rare. Only one specimen collected in a backwater area in the lower section of the river.

Etheostoma radiosum (Hubbs and Black) - Orangebelly darter - 1, 2,3,4,5,6,7,8,9,10,11,12,14,15,16.
Most common darter throughout the river.

Etheostoma stigmaeum (Jordan) - Speckled darter - 7,16.
Uncommon. Found mainly in quiet waters.

Etheostoma whipplei (Girard) - Redfin darter - 15.
Uncommon. Found only in the lower section of the river.

Etheostoma zonale (Cope) - Banded darter - 4,5,7,8,14,15.
Common. Found mainly in riffle areas.

Percina caprodes (Rafinesque) - Logperch - 3,4,5,6,7,8,9,10,11,13, 14,15,16.
Common throughout the river.

Percina copelandi (Jordan) - Channel darter - 15,16.
Uncommon. Found only in lower section of river.

Stizostedion vitreum vitreum (Mitchill) - Walleye - 14,16.
Uncommon. Five specimens collected in lower section of river.

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Movements of Channel Catfish and Flathead Catfish In Beaver Reservoir, Northwest Arkansas

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ABSTRACT

A total of 497 channel catfish, *Ictalurus punctatus*, and flathead catfish, *Pylodictis olivaris*, were tagged in Beaver Reservoir during two November-April tagging periods (1967-68 and 1968-69); total recaptures were 9.5 and 11.7% respectively. The longest time between tagging and recapture was 1622 days (4.4 years) for channel catfish and 494 days (1.4 years) for flathead catfish. The longest distances traveled were 43.1 km by a channel catfish and 44.3 km by a flathead catfish. Fisherman returns indicated that catfish were caught primarily from April through July. The many recaptures, even after long periods, within 1.6 km of the tagging point, suggested that fish moved little, or had homing tendencies. Captures of fish in trap nets indicated that rainfall and inflow possibly stimulated movements of channel catfish during the winter and early spring.

INTRODUCTION

Studies of the movements of channel catfish, *Ictalurus punctatus* (Rafinesque), and flathead catfish, *Pylodictis olivaris* (Rafinesque), in lakes and reservoirs have been limited. Hancock (1954) reported 2 returns from 97 channel catfish and no returns from 4 flathead catfish marked in Fort Gibson Reservoir, Oklahoma. At Utah Lake, Utah, 18 of 1,957 fin-clipped channel catfish were recaptured, but only 4 were recaptured outside the immediate area of tagging (Lawler, 1960). Hart and Summerfelt (1974) defined the home ranges and movements of flathead catfish at Lake Carl Blackwell, Oklahoma, by using sonic tags. Houser (1960) reported a high incidence of homing (about 37% of recaptures) by channel catfish in Lake Lawtonka, Oklahoma, during a study in which trap nets were used to capture fish and jaw tags to mark them. We describe movements and speculate about conditions that cause movement of tagged channel catfish and flathead catfish in Beaver Reservoir, Arkansas.

METHODS

Beaver Reservoir is in the upper White River basin in northwest Arkansas. At conservation pool elevation, the reservoir has a surface area of 11,445 ha and a storage capacity of 2,037,725 $m^3 \times 10^3$. Three major streams enter the reservoir: White River, War Eagle Creek and Richland Creek.

Nearly all fish were captured with Ederer submarine trap nets (nine channel catfish by electrofishing), during two periods of trap net fishing: November, 1967 through April, 1968 and November, 1968 through April, 1969. Four 2.7-m-deep trap nets were fished during the first period, and the same four nets plus two 1.8-m-deep trap nets during the second period. The trap nets were usually lifted every 3 to 4 days, except in late March when the nets were lifted once each week. The trap nets had leads 30.5 to 91.4 m long. The nets were fished at several locations, primarily in the upper half of the reservoir.

The collection of catfish by electrofishing was restricted to the upper White River and War Eagle Creek, 1 to 3 km above the reservoir pool, in late March and April, and was incidental to the collection of white bass, *Morone chrysops* (Rafinesque), for making studies (none of the nine catfish taken by electrofishing was recaptured). The Floy FD-67 internal anchor tag was used to mark most of the catfish captured, but a few dart-type internal anchor tags were used during the first tagging period. Tagging methods and equipment were described by Dell (1968) and Thorson (1967). In the present study, tags were placed on the left side of the fish below the adipose fin.

Tag recovery forms supplied to fishermen requested information on species, location and date of recapture, and the tag number. Reservoir maps were used to compute the shortest distances between locations of marking and recapture in the lake. All length measurements given are in total length. Recaptures in our trap nets were recorded and the fish released.

Data on rainfall and inflow were abstracted from Monthly Reservoir Operation data sheets prepared by the U. S. Army Corps of Engineers, Little Rock District, Little Rock, Arkansas.

RESULTS

Channel Catfish: A total of 497 channel catfish 220 to 710 mm TL (mean 398 mm TL) were tagged in the study. There were 47 recaptures (9.5%) during the four years following tagging (Table I). Anglers returned 38 tags (81%), and 9 tags (19%) were recovered in our trap nets. The longest time interval between tagging and recapture was 1622 days (4.4 years) with the mean interval of 195 days. An analysis of the movements of channel catfish by season, distance, days, and direction from tagging to recapture (Table II) showed that recaptures were made in every month except September, November, and December. The highest number (13) occurred in May.

The maximum distance traveled was 43.1 km (upstream from the tagging point), and the mean distance was 6.1 km. Of 47 recaptures, 11 were recovered upstream, 18 downstream, and 18 within 1.6 km of the tagging point; 36 (76%) were recaptured within 8.0 km of the point of tagging.

The numbers of channel catfish in the trap net catches increased after heavy rainfalls and associated high inflows during the period December through February (Fig. 1). Light rainfalls in late December, 1967 and early January, 1968 were followed by high catches of channel catfish. Heavier rainfall in late January, 1968 was followed by increased catches. Catches increased from late February to mid-March, 1968, during early spring rains. Heavy rain and high inflows on December 26 to 29, 1968, and January 28 to 30, 1969, were followed by the highest catches recorded. The high catches of February 24, 1969, appeared to indicate increased activity of channel catfish associated with spring warming trends.

Flathead Catfish: One hundred seventy-one flathead catfish were tagged during the two tagging periods (Table I). The total length ranged from 400 to 1020 mm, with a mean total length of 714 mm. There were 20 recaptures (11.7%), 15 (75%) by anglers and five

Table I. Summary of channel and flathead catfish tagging and recaptures by tagging period, percent, and year of recapture in Beaver Reservoir, Arkansas.

Species and tagging period	Number tagged	1967-68 No.	1967-68 %	1968-69 No.	1968-69 %	1970 No.	1970 %	1971 No.	1971 %	1972 No.	1972 %	1973 No.	1973 %
Channel Catfish													
1967-68	197	11	5.6	0	-	0	-	0	-	0	-	0	-
1968-69	300	-	-	30	10.0	1	0.3	3	1.0	1	0.3	1	0.3
Totals	497	11	2.2	30	6.0	1	0.2	3	0.6	1	0.2	1	0.2
Flathead Catfish													
1967-68	94	9	9.6	1	1.1	0	-	0	-	0	-	0	-
1968-69	77	-	-	8	10.4	2	2.6	0	-	0	-	0	-
Totals	171	9	5.3	9	5.3	2	1.2	0	-	0	-	0	-

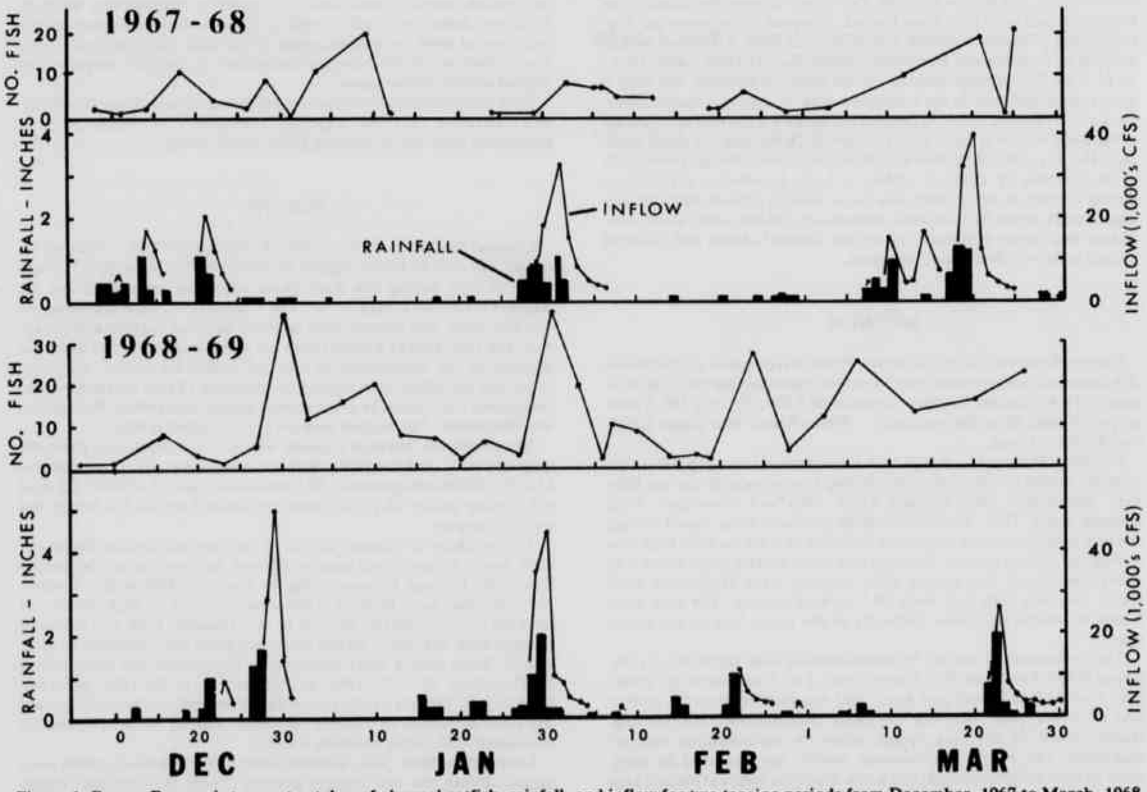

Figure 1. Beaver Reservoir trap net catches of channel catfish, rainfall, and inflow for two tagging periods from December, 1967 to March, 1968 and December, 1968 to March, 1969. The rainfall and inflow data are taken from U. S. Army Corps of Engineers reports which are reported in the English units used here.

Table II. Channel catfish and flathead catfish recaptures upstream, downstream, and within 1.6 km of the tagging point in Beaver Reservoir, Arkansas, from 1967-68 and 1968-69 tagging period (data combined). (CC = channel catfish; FH = flathead catfish)

Months of recapture, distance from tagging site, and days at large[a]	Upstream		Downstream		Within 1.6 km		Total	
	CC	FH	CC	FH	CC	FH	CC	FH
Months								
January	-	-	-	-	2	1	2	1
February	-	-	-	-	1	1	1	1
March	-	1	-	1	5	1	5	3
April	3	-	1	2	3	-	7	2
May	4	5	5	1	4	1	13	7
June	3	3	2	-	2	1	7	4
July	-	1	7	-	-	-	7	1
August	-	-	2	1	1	-	3	1
October	1	-	1	-	-	-	2	-
Kilometers								
0-1.6	-	-	-	-	18	5	18	5
1.7-8.0	5	2	13	3	-	-	18	5
8.1-16.1	3	4	4	1	-	-	7	5
16.2-24.1	2	1	1	1	-	-	3	2
24.2-32.2	-	1	-	-	-	-	-	1
> 40.3	1	2	-	-	-	-	1	2
Days at large								
1-10	-	-	-	1	3	3	3	4
11-20	-	-	-	1	1	-	1	1
21-50	2	2	-	-	5	1	7	3
51-100	3	-	5	2	5	-	13	2
101-150	4	2	7	-	2	-	13	2
151-200	-	3	1	-	1	-	2	3
201-250	2	2	-	-	-	-	2	2
351-400	-	1	-	-	-	-	-	1
451-500	-	-	-	1	-	1	-	2
501-1000	-	-	3	-	1	-	4	-
1001-1650	-	-	2	-	-	-	2	-
Total recaptures	11	10	18	5	18	5	47	20

[a]No recaptures in September, November, or December; no recaptures of fish that moved 32.3-40.2 km; and no recaptures of fish that were at large for 251-350 or 401-450 days.

(25%) in our trap nets. Flathead catfish recaptures and movements by season, time, and direction from tagging to recapture are given in Table II. There were seven recaptures (35%) in May, four (20%) in June, three in March, two in April, and one in January, February, July and August.

The longest interval between tagging and recapture was 494 days (1.4 years); mean interval was 86.9 days. The longest distance traveled was 44.3 km, shared by two fish.

DISCUSSION

The trap nets intercepted catfish during migration or movement within their home ranges. Because there were no multiple recaptures, it is difficult to distinguish migration from movement within the home range. Houser (1960), reported that about 37% of 96 total recaptures from 1002 marked channel catfish were in the trap where the fish were caught and tagged. His fish were released at distances of 1,450 to 6,180 feet from the trap captured, and the highest recapture numbers in the traps of original capture came from the longest distances, indicating strong homing trends. In the present study, two channel catfish were at large 2.7 and 2.6 years after tagging and recaptured 2.4 and 1.6 km, respectively, from the tagging point, also suggesting strong home range orientation. Of the downstream recaptures, seven (39%) were recaptured in July, and two in August. These data suggest that channel catfish migrate back to a home range area after having completed a spring upstream migration. Flathead catfish displaced and tracked with sonic gear at Lake Carl Blackwell tended to return to their original home range area (Hart and Summerfelt, 1974). In the present study one flathead catfish was recaptured about 0.4 km from the tagging point 481 days (1.3 years) after tagging. Other flathead catfish were recaptured within 1.6 km of the tagging point of to 24 days after tagging, suggesting that we had intercepted their movements within a home range. Hart and Summerfelt (1974) were able to show catfish movement capabilities for a short period of time, such as 2,216 m in 39.5 h, or 58.6 m/h. In our study the time required to move a measured distance was predicated on recaptures and did not allow the measurement of lateral movement, velocities for short periods, or depth distribution patterns.

Four of our tagged fish moved considerable minimum measured distances upstream between tagging and recapture. A channel catfish was recaptured 16.6 km 31 days after tagging and three flathead catfish were recaptured 28.9 km in 35 days, 44.3 km in 170 days and 44.3 km in 202 days after tagging, all suggesting a spring migration and temporary departure from the home range.

Movements of channel catfish during the winter have not been documented. There was evidence that winter movement or activity was stimulated by rainfall, reservoir inflows, or a combination of both conditions. Catches of channel catfish in trap nets during the winter were higher after a period of inflow greater than 282 m^3/sec. (10,000 cfs) or a rainfall of 2.5 cm (1 in.) or more (Fig. 1) with two exceptions: (1) late December, 1967, and (2) mid to late February, 1969. During those periods, catches exceeded ten fish and rainfall was less than 10 cm (0.5 in.), or inflow was less than 142 m^3/sec. Alabaster (1970) found that the movements of salmonids in rivers were influenced by conditions associated with naturally occurring freshets, rather than with a high flow. Although no temperature data are available for the years of our study, Beaver Reservoir minimum temperatures (below 10°C) from 1964 to 1967 were reached by late February (Mullen et al., 1970). From the data it is believed that rainfall and inflow increase the movements of catfishes.

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Distribution of Bats in the Delta Region of Northeastern Arkansas

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ABSTRACT

Eight taxa of bats are reported from seven counties in northeastern Arkansas. Localities, natural history notes, sex, age and reproductive condition are reported for most species. New records are combined with previously existing ones to reveal a greater distribution of chiroptera for the state.

INTRODUCTION

The Mississippi River Delta of northeastern Arkansas is a region in which agricultural practices dominate. As a result of overcutting, burning, and clearing land for farming operations, habitat needed to support bat populations has been drastically reduced. Soil Conservation Service figures for 1975 indicate that woodlands comprise less than 15% of the total area of Craighead, Cross, Greene, Jackson, Mississippi, and Poinsett Counties.

Although bats undoubtedly occur throughout the Delta Region of northeastern Arkansas, previously published records for this area are virtually non-existent. Sealander (1956) reported records for only two species of bats for one county in this region. Baker and Ward (1967) list records for nine species of bats which occur in three counties of southeastern Arkansas. Other existing records of chiroptera for the state are concerned primarily with the Ozark Region, and caves found therein, of northwestern and northcentral Arkansas (Dellinger and Black, 1940; Sealander, 1956, 1960; McDaniel and Gardner, 1977). Graves and Harvey (1974) reported twelve species of bats occurring in all or part of 21 counties in western Tennessee.

METHODS

Localities are reported for eight species of bats collected from seven counties in northeastern Arkansas between 1973 and 1977. Although many specimens were collected by the author, a number of records existed in the Collection of Recent Mammals, Arkansas State University.

Collection was primarily by mist netting, as described by Tuttle (1976). Japanese mist nets of variable lengths (18.3, 12.8, and 5.5 m), were set in the capture position just prior to sunset, and checked at intervals of 30 minutes during the night, until sunrise. Most netting was done over water, either over creek pools or on ponds, to capture bats as they drank. However, nets were also set in flyways created by roads through woods, dry streambeds, buildings, or bridges. Each bat was removed from the net and the following data recorded for each capture: species, time of capture, sex, age, reproductive condition, and certain environmental conditions (e.g. temperature, precipitation, cloud cover, and moon phase). Other collecting techniques included the searching of abandoned houses, barns and bridges. Only voucher specimens were prepared and deposited in the Collection of Recent Mammals, Arkansas State University, the remaining individuals were recorded and released.

Assignment of bats into age classes was determined by closure of phalangeal epiphyses. Bats were designated as juveniles on the basis of small overall size, as well as incomplete ossification of the epiphyses. In some instances, sub-adult bats were determined by lack of canine wear, but more reliably by the condition of the epiphyses of the phalanges and humerus. Comparison of pelage color was helpful in separating juvenile and sub-adults from adults.

Reproductive condition of males was determined by position of the epididymides. Scrotal bats were characterized by complete descent of the epididymides into pigmented sheathes dorsolateral to the tail, and by the presence of enlarged testes. Female bats were diagnosed as pregnant by dissection, or by examination of an obviously enlarged abdomen. Lactation was determined on the basis of teat examination and the obvious presence of lactiferous tissue.

DISTRIBUTION AND NATURAL HISTORY NOTES OF BATS IN NORTHEASTERN ARKANSAS

Myotis lucifugus (LeConte). Typically a cave inhabitant, the little brown bat occurs more commonly in small numbers throughout the Ozark Region of Arkansas. The nearest existing records were from caves in Independence County (McDaniel and Gardner, 1977). On 8 October 1976 a scrotal male was netted in Craighead County over Ditch Number 60 (a tributary of the Saint Francis River), and on 15 October 1976 another scrotal male was collected from the same location. The latter specimen was a sub-adult, as its pelage was not characteristic of adult bats. These specimens represent the first records for this species in northeastern Arkansas.

Lasionycteris noctivagans (LeConte). Baker and Ward (1967) reported five specimens captured in December in Bradley County. Previously, Sealander (1956) listed only two specimens from northwestern Arkansas. On 15 October 1974 an adult male was found hanging on a brick wall in the newly completed Agricultural Sciences Building, Arkansas State University. On 18 May 1977 another male was netted over Poplar Creek, Greene County. Poplar Creek cuts directly across Crowley's Ridge, and is surrounded on either side by upland deciduous hardwood forest, representing one of the few remaining habitats favorable to species of tree bats.

Pipistrellus subflavus (F. Cuvier). The eastern pipistrelle is most commonly a cave inhabitant, but females are known to regularly establish nursery colonies outside caves (Lowery, 1974), and to roost in a variety of situations, including trees (Findley, 1954). On 17 May 1973 a female was collected from a group of 10 bats found beneath a concrete bridge across the Cache River, Lawrence County. Another adult female was found hanging from the supporting rafters of a porch in Green County. On 28 April 1977 an adult female was netted during a light rain over Ditch Number 60 in Craighead County. According to Baker and Ward (1967), this species decreases in numbers during late August and September, which also seems to be the case in northeastern Arkansas since no specimens were collected during fall or winter. However, this seasonal effect is probably due to hibernation or migration on south.

Eptesicus fuscus (Ralisot de Beavois). Sealander (1956) reported a single specimen of the big brown bat from Greenway, Clay County. Only three other specimens are presently known from northeastern Arkansas. A dead adult male was found in a parking lot near a church belfrey in Jonesboro, Craighead County, on 8 February 1977. On 22 October 1977 an adult female bat was discovered dead on the theatrical stage in Wilson Hall, Arkansas State University (search of the attic revealed only a small ventilator through which a bat could enter the building, and no additional bats were found). Four days later, on 26 October, a male was collected in mid-afternoon on the west side of the First National Bank Building in Jonesboro.

Lasiurus borealis (Muller). Sealander (1956) reported only five specimens of the red bat from one locality in the extreme corner of northeastern Arkansas. This species is unquestionably the most commonly occurring in the Delta Region. From May, 1976 to October, 1977, a total of 81 red bats were captured or observed. On 26 June 1973 a female with three young attached was discovered hanging from a porch rafter in Jonesboro, Craighead County. One year later, on 25 June, a female was found in Walnut Ridge, Lawrence County, also with three young attached (one male and two females). Another female with three young attached (one male and two females), was discovered on the Arkansas State University campus on 25 June 1975. On 18 May 1977 a pregnant red bat (with one female and two male embryos, crown to rump average-15 mm), was netted over Poplar Creek, Greene County. On 13 June 1977 in Paragould, Greene County, a female with four young attached was found on the ground beneath a tree. The average weight of these young was 6.9 g while the female weighed 15.5 g. On 16 June 1977 another female red bat was discovered three km north Jonesboro, beneath a shagbark hickory (*Carya ovata* [Mill.] K. Koch). This bat had only two young attached and was discovered after observing the peculiar behavior of a pair of blue jays (*Cyanocitta cristata* [Linnaeus]). The two birds were observed molesting the female, and successfully dislodged her from the tree. Blue jays are known predators on red bats (Hoffmeister and Downes, 1964). During the night of 8 June 1977, a total of fifteen red bats were netted over a very small isolated water hole on Cooper Creek, Cross County. With the exception of one scrotal male, all specimens were females. Eight of the females were lactating, one was pregnant, one was later determined to be a sub-adult, and another was a juvenile. Cockrum and Cross (1964) stated that pregnant, and especially lactating females may require more water than males, and may not be able to maneuver and avoid a mist net as easily as males or nonpregnant females. At present there is only a single specimen of the red bat from Mississippi County—a female shot feeding around a street light four km west of Manila. An adult male red bat was captured in Jackson County, near Newport, on 27 February 1977, and a juvenile was shot at the same location on 8 April 1977.

Lasiurus borealis was collected in a variety of situations in northeastern Arkansas, including under brush piles, from the rafters of porches, and attached to the node of cane (*Arundinaria gigantea* [Walt.] Chapm.). However, they were most often collected along streams or riparian habitats. The majority of specimens was collected on or near Crowley's Ridge, in extensively wooded areas. Only one red bat (an adult female) was collected in December, near Jonesboro. However, there were several sightings of unidentified bats during December occurring in locations where red bats previously had been captured. Although no bats were captured during January or March, a male was collected on 11 February 1977 north of Jonesboro. This specimen was observed flying down a county road in mid-afternoon, and was captured after it landed on the shoulder of the road. Another bat, which appeared to be a red bat, was observed flying approximately 9 m above a road in Cross County on 26 February 1978. These data suggest at least limited winter activity of red bats during warmer days.

Lasiurus cinereus (Palisot de Beauvois). Baker and Ward (1967) reported 14 specimens of the hoary bat from southeastern Arkansas. Sealander (1956) reported a total of six specimens from the state. On 4 September 1976 an adult female was netted at 3:00 a.m. over a small pool on Poplar Creek, Greene County. On 18 May 1977 a pregnant female (containing two male embryos, crown to rump average - 19 mm), was captured at the same locality. A torpid male was discovered beneath the eave of a house in Jonesboro on 8 March 1978. Another male was collected from a low hanging branch of an oak (*Quercus* sp.), Woodruff County.

Nycticeius humeralis (Rafinesque). The evening bat appears to be more numerous in the southernmost counties of Arkansas (Baker and Ward, 1967), and farther south into Louisiana (Lowery, 1974). Only six specimens were collected from northeastern Arkansas. A scrotal male was netted on 15 October 1976 as it flew down a well-canopied stream adjacent the Saint Francis River, Craighead County. Another scrotal male was netted on 19 November 1976 over a pond north of Jonesboro. On 23 January 1977 an adult male was discovered clinging to the side of an old chair on the back porch of a house 15 km west of Jonesboro. Another scrotal male was shot as it emerged at sunset on 4 May 1977 near the Saint Francis River, Craighead County. This bat flew considerably lower than the surrounding trees, and was the first bat observed on that particular night. A sub-adult male was netted at a different location on the Saint Francis River on 23 June 1977, Greene County. Although evening bats were not commonly encountered in northeastern Arkansas, they appear to be present in small numbers during much of the year.

Plecotus rafinesquii Lesson. Sealander (1956) lists only a single record of this bat for the state. Several specimens and a nursery colony were reported by Baker and Ward (1967). A total of six specimens were collected from the Delta Region of northeastern Arkansas. On 2 November 1973 a scrotal male was collected from a barn three km east O'Kean, Greene County. Another scrotal male was discovered hanging half way up a wall in an old house 9 km west of Tuckerman in Jackson County, on 14 June 1974. During the night of 18 September 1976 two adult females were netted as they flew down Cooper Creek, Cross County, and on 24 September 1976 a scrotal male was netted over the creek. These bats were presumably breeding in this vicinity as the testes of the males were approaching maximum development. Another scrotal male was netted on 8 October 1976 as it flew down Ditch Number 60, Craighead County. These records represent a greater distribution of the eastern bigeared bat for Arkansas than previously reported. The unusually large number of old and abandoned houses and barns, as well as other suitable roosting sites, provide excellent habitat for this species in northeastern Arkansas.

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Renovation of Nitrogenous Wastewater Via Land Application[1]

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ABSTRACT

Removal of inorganic and organic nitrogen from wastewater prior to recharge of ground and surface waters can be accomplished by judicious land application. This study focused attention upon the feasibility of using sprinkler irrigation as the wastewater delivery system with coastal bermudagrass (*Cynodon dactylon* L., var. coastal) pasture as the wastewater sink. One site was located on a Sawyer soil near El Dorado, while the other was located on a Savannah soil near Malvern. This report is limited to the renovation of surface waters. Results revealed that nitrogen concentration in runoff water from rainfall was substantially less than nitrogen concentration of the wastewater applied to the soil and similar to background levels. Such results support the consideration of land application as a viable wastewater disposal method.

INTRODUCTION

A major goal in the renovation of industrial wastewaters should be to recover and recycle wastewater components which are considered pollutants if discharged directly into surface waters. When these components are plant nutrients, this goal can be achieved by properly integrating wastewater management with conventional cropping systems (Pound and Crites, 1973). Toward this end, site selection, irrigation method, loading rates and crop management must be considered to optimize the renovation process (Pound and Crites, 1973).

The objective of this study was to evaluate the potential of sprinkler irrigation on pasture at two sites in Arkansas as a wastewater renovation procedure. Surface water nitrogen concentrations were the variables used in this evaluation.

METHODS AND MATERIALS

Site 1 was located near El Dorado, Arkansas, on a Sawyer soil (fine-silty, siliceous, thermic, Aquic Paleudult) with 2 to 5 percent slope. In 1975, coastal bermudagrass (*Cynodon dactylon* L., var. coastal) pasture was established at the site and a stationary sprinkler irrigation system installed on three 0.74 ha rectangular plots. Each plot was surrounded by a levee in which a runoff outlet, a V-notch weir, was installed. Sample tubes were connected to the weir in a manner which allowed individual samples (about 1 sample per each 2.5 cm head) to be collected during rising and falling stages of a given runoff event. Runoff volume was measured with a water stage recorder. Runoff results reported here were from rainfall events and not from runoff which may have occurred during irrigation. When irrigation was improperly conducted, the infiltration capacity of the soil was exceeded and runoff occurred. The nitrogen concentrations in the latter were similar to the nitrogen concentrations in the applied effluent (data not shown).

Site 2 was located near Malvern, Arkansas, on a Savannah soil (fine-loamy, siliceous, thermic, Typic Fragiudult) with 0 to 1 percent slope. In 1975, coastal bermudagrass pasture was established and a staionary sprinkler irrigation system installed on three 0.10 ha circular plots. These plots were instrumented and measurements made as described for Site 1 above.

At each site, fertilization, liming, weed and insect control, harvest frequency and the like were representative of the management inputs used by farmers in the site area. Control plots received no management inputs except harvest.

The effluent was applied at weekly or biweekly intervals during the growing season (April to September). At Site 1, three plots received effluent (3 to 9 cm applied) at rates of about 400, 700 and 1100 kg N/ha, respectively, during the growing season. The data reported in Table I are average values for the 3 plots. Control data for Site 1 were obtained from an unirrigated plot identical to the above except that vegetation was native and not coastal bermudagrass. At Site 2, three plots received approximately 300, 600 and 900 kg N/ha/year, respectively, during each season. In 1976, from 7 to 21 cm of effluent were applied, while in 1977, 17 to 46 cm of effluent were applied. The data reported in Table II are average values from the 3 plots. Control data for Site 2 were obtained from an unirrigated plot identical to the plots irrigated with effluent.

Water samples were treated with phenylmercuric acetate and refrigerated prior to analysis. Ammonium, nitrate (plus nitrite) and organic nitrogen were determined by the semi-micro Kjeldahl procedure (Bremner, 1965). Runoff data for Site 1 are volume-weighted averages, while those from Site 2 are unweighted averages. Irrigation data reported for both sites are unweighted averages.

RESULTS AND DISCUSSION

Land application of nitrogenous effluent was evaluated by comparing the nitrogen (N) concentrations in runoff with the N concentrations in: a) effluent used in irrigation, b) runoff from other events, and c) receiving streams. For the purposes of this discussion, it was assumed that runoff did not occur during effluent application and that renovation was shown when a decrease in the N concentrations from input (irrigation) to output (runoff) waters was measured. Thus, renovation considered surface water quality entering and leaving the pasture and did not consider the behavior of nitrogen or water within the pasture itself.

Tables I and II present the average nitrogen concentrations in irrigation and runoff waters for Sites 1 and 2, respectively, during the growing season. In all cases, the nitrogen concentration in the runoff water was substantially smaller than that in the irrigation water. The NH_4-N concentration decreased by 99 percent at Site 1 and from 75 to 83 percent at Site 2. The NO_3-N concentration also decreased at Site 1 (97%), while a 93 to 97 percent NO_3-N decriment was measured at Site 2. Data from Site 2 pointed out that organic-N concentrations decreased by 88 to 95 percent. These reductions in NH_4-N, NO_3-N and organic-N represent a substantial renovation of the original wastewater which equals or surpasses that attainable through conventional or advanced treatment schemes (D. T. Mitchell, *per. comm.*). Conventional water treatment plants do not alter NO_3-N concentrations, while NH_4-N concentrations of somewhat less than 5 ppm result when near optimum methods of NH_4-N removal are employed. Advanced wastewater treatment schemes which have been proposed, but not yet applied on a large scale, would probably achieve concentration reductions similar to those reported here (D. T. Mitchell, *per. comm.*).

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Table I. Summary of irrigation and runoff water quality during the 1976 growing season at site 1.

Water	NH_4-N	NO_3-N
	ppm	
Irrigation	796	380
Runoff*	7	11

*Average NH_4-N plus NO_3-N concentration from the control plot was about 1 ppm.

Table II. Summary of irrigation and runoff water quality during the 1976-77 growing seasons at site 2.

Water	NH_4-N		NO_3-N		Org-N	
	1976	1977	1976	1977	1976	1977
	ppm					
Irrigation	6	4	131	59	329	118
Runoff*	1	1	1	4	13	14

*Average NH_4-N, NO_3-N and Org-N concentrations during 1976-77 from the control plot were 1, 1 and 3 ppm, respectively.

Another measure of wastewater renovation was comparison of the nitrogen concentrations in the runoff water with those of other runoff waters. For example, at Site 1 the control plot yielded runoff waters with an average NH_4-N plus NO_3-N concentration of about 1 ppm, while that from the sprinkler irrigated plots averaged 18 ppm. At Site 2, NH_4-N and NO_3-N concentrations in runoff for control and irrigated plots were similar, while organic-N concentrations were about 10 ppm higher in plots receiving effluent as compared to controls. In a Missouri study runoff waters from pastures amended with 170 kg N/ha as NH_4NO_3 averaged 2.5 ppm NO_3-N and 1.3 ppm NH_4-N over a 3 year period (Schuman *et al.*, 1973). These concentrations are intermediate to those reported here which suggests that our results are within the range of those expected for a pasture fertilized in a conventional manner. Schreiber *et al.* (1976) measured about 0.1 ppm NO_3-N and from 0.5 to 1.1 ppm NH_4-N in runoff waters from 5 southern pine watersheds. These results are similar to the data reported here for the control plots. Thus, the concentrations of NH_4-N and NO_3-N in runoff appeared greater than would be expected in a native or control environment, but were similar to that expected for a pasture receiving recommended amounts of nitrogen as fertilizer applied in a conventional manner.

A final comparison used to test renovation efficacy was contrasting the nitrogen concentrations in runoff waters (Table I and II) with those in receiving streams. Only NO_3-N data were available in the STORET computer file of surface water quality data (D. B. Beasley, *per. comm.*) for this comparison. Data from October, 1973 to October, 1977 for Smackover Creek (Sample Station OUA27) and from October, 1971 to October, 1977 for the Ouachita River (station OUA07A), both receiving streams for Site 1, showed NO_3-N concentration averages of 0.2 and 0.5 ppm, respectively. Data from October, 1973 to October, 1977 for the Saline River (station OUA26), the receiving stream for Site 2, yielded an average NO_3-N concentration of 0.2 ppm. Thus, even with the reduction in NO_3-N concentration obtained via sprinkler irrigation, the NO_3-N concentrations in runoff waters were larger than those of the receiving stream.

In summary, substantial reductions in wastewater N concentrations were achieved, and runoff N concentrations were within expected limits. However, NO_3-N levels in runoff were larger than those in receiving streams. These results and attendant discussion point out that land application of nitrogenous effluent by sprinkler irrigation yields surface recharge water (runoff from rainfall) much less likely to measureably increase N concentrations in the receiving stream than direct discharge of the effluent.

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Species Composition and Diversity of Hawk Populations in Northeastern Arkansas

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ABSTRACT

Species composition and diversity of hawk populations were analyzed for northeastern Arkansas by the use of roadside censuses conducted in September through April from 1974-1977. Data from 10 years of Jonesboro Christmas Bird Counts were also analyzed.

During the roadside survey 20,174 miles were driven and 1819 raptors were counted. Ten species were observed with the Red-tailed Hawk being most abundant followed by the Marsh Hawk and the American Kestrel. Eight species were recorded from the 10 years of Christmas Bird Counts. Annual breeding bird surveys and spot records turned up three additional species making a total of 14 species in 15 years of study.

Although hawk populations fluctuate from year to year, the data do not reveal any downward trend in numbers in northeastern Arkansas. Large concentrations of hawks do not appear in this region of the state until after mid-September. Populations reach a peak in December after which they decline in January. A second peak is reached in February followed by a gradual decline such that in April the American Kestrel is the only species consistently seen from the roadside. After April only a few hawks remain to nest.

Both Krider's and melanistic Red-tails occur here but from a total of 864 Red-tailed Hawks observed only 26 Krider's and 31 melanistic or *Buteo jamaicensis harlanii* were recorded.

INTRODUCTION

In this paper we investigate the seasonal and long term species composition and relative abundance of hawks in the northeastern section of Arkansas. Data from roadside censuses and Christmas bird counts were analyzed in this study. The roadside census, which is a method of determining relative abundance, not absolute abundance, was used by Nice and Nice (1921) to study Oklahoma bird populations as early as 1920. Since then many workers have employed this technique. Howell (1951) made detailed studies using relative conspicuousness in determining bird numbers along roadsides in Tennessee while Peterle and Eherhardt (1959) reported on the variability of this method in studying the Cottontail Rabbit. Also, many wildlife personnel have used the roadside census to study population trends for mammals and game birds (Fisher et al., 1947; Hendrickson, 1939; Lord, 1959 and 1961; Newman, 1959; Wight, 1959; and Wortham and Hanebrink, 1970). Kendeigh (1944) evaluated the roadside census in relation to other types of censuses used to study birds, and Dice (1930 and 1952) thoroughly discussed and compared numerous census methods.

METHODS

A total of all falconiform species was completed for September through April from 1974 through 1977. There are few summer resident hawk species in northeastern Arkansas. Breeding bird censuses taken in June for ten northeastern Arkansas counties for 1971 and eleven years of breeding bird censuses in three counties revealed only three species, the Turkey Vulture *(Cathartes aura)*, the Mississippi Kite *(Ictinia mississippiensis)* and the Red-shouldered Hawk *(Buteo lineatus)*. A few Red-tailed Hawks *(Buteo jamaicensis)*, Cooper's Hawks *(Accipiter cooperii)* and possibly American Kestrels *(Falco sparverius)* and Sharp-shinned Hawks *(Accipiter striatus)* nest in this region of the state but numbers have not been high enough to appear on annual breeding surveys.

Relative conspicuousness as reported by Howell (1951) is not a great factor in determining winter hawk populatins since most winter species perch in open places such as telephone wires and poles and trees without leaves. These species can be easily identified from an automobile and are all equally conspicuous. The exception is the Marsh Hawk *(Circus cyaneus)* which flies low over stubble and open fields and generally perches on the ground.

In northeastern Arkansas, migratory hawks are seldom numerous before the middle of September and roadside censuses before this time give very low counts. Thus, fewer miles were driven during the earlier part of this month.

All types of roads and highways were traveled including Interstate 40 between Memphis and Little Rock. Normal speeds were driven during early morning and late afternoon.

Long term population trends were based on the Jonesboro Christmas Bird Count data for 1967 through 1976. Since the interpretation of quantitative data from Christmas bird counts is difficult because of the many variables involved, such as time spent in the field, locality, weather, habitat, period of day spent in the field, number and competence of observers and methods of travel (Graber and Golden, 1960). Stewart (1954: 192) has suggested that such data be used to show general trends only. It is impossible to eliminate all or even some of the major sources of variation and most of the variables were present throughout the census period, but hopefully were not operating in any one direction to produce undue bias. The Jonesboro Christmas Counts (Hanebrink, 1968-1977) were somewhat standardized as each covered an eight-hour period with four parties observing. The number of individuals in each party often varied, but there was at least one competent observer in each party.

All species names used in this paper are based on the A.O.U. Check-list of North American Birds, Fifth Edition (1957) and the 32nd Supplement to the A.O.U. Check-list of North American Birds (1973).

DESCRIPTION OF AREA

All of northeastern Arkansas is extensive delta with the exception of Crowley's Ridge. The flat land reaches the base of the Ouachita hills at the edge of North Little Rock. It then continues north into southeastern Missouri and south into Louisiana without any natural break. Crowley's Ridge runs for a distance of 200 miles from southeastern Missouri down to the Mississippi River at Helena, Arkansas. Accounts of the geology of Crowley's Ridge are given by Call (1891), and Magill (1958) summarizes the various theories concerning the origin of the ridge. Another important topographical feature in northeastern Arkansas is the "sunken lands" of the St. Francis River area, Big Lake and Wapanocca. These areas had their origin with the New Madrid Earthquake of 1811-1812 (Magill, 1958). The area censused by automobile included all counties of the delta and Crowley's Ridge to the foothills of the Ozarks and as far south and west as West Memphis, Brinkley and Little Rock (Fig. 1).

RESULTS AND DISCUSSION

Lowland deciduous woods in northeastern Arkansas have been destroyed at a rapid rate by slash clearance. These once swampy areas are now planted in cotton, soybeans, wheat and rice. Destruction of swampy woods has decreased wildlife habitat over vast areas of northeastern Arkansas delta so that many species of raptors are forced into poor cover along roadsides. However, much of their food comes from dead animals that have been killed by automobiles.

Seasonal Trends in Hawk Populations:

During the roadside survey 20,174 miles were driven, and a total of 1819 raptors were observed (Table 1). During these surveys the number of miles driven differed each month so the total number of hawks seen per month is a meaningless figure. All numbers given in tables and figures are expressed as numbers of hawks per 100 miles of travel.

Ten species were recorded with the Red-tailed Hawk being most abundant followed by the American Kestrel and the Marsh Hawk. Turkey Vultures were rare in the delta area and were recorded mainly from Crowley's Ridge and areas near the edge of the Ozarks near Batesville and Pocohontas. Because of the small acreage of wooded area, Red-shouldered Hawks, Cooper's Hawks and Sharp-shinned Hawks were rarely recorded. Broad-winged Hawks *(Buteo platypterus)* do not winter here but do migrate through during the spring and fall; however, they usually fly high and are seldom observed during roadside censuses. Rough-legged Hawks *(Buteo lagopus)* are extremely rare in northeastern Arkansas and have only been recorded during the past few years.

Red-tailed Hawks of northeastern Arkansas belong to three subspecies and show much variation in color pattern. The sub-species are *Buteo jamaicensis borealis, B. j. kriderii* and *B. j. harlani* with *B. j. borealis* by far the most abundant form (Fig. 2). Only *B. j. borealis* spends the entire fall and winter season from September until April in this area. Krider's Red-tailed Hawk *(B. j. kriderii)* does not arrive until October and leaves in March while *B. j. harlani* and melanistic *B. j. borealis* have not been recorded before November, and they too leave in March (Fig. 2).

The Bald Eagle *(Haliaeetus leucocephalus)*, the Golden Eagle *(Aquila chrysaetos)* and the Osprey *(Pandion halioetus)* have all been observed in northeastern Arkansas although the Golden Eagle occurs only rarely. However, the Bald Eagle and the Osprey often frequent Big Lake, Wapanocca and Claypool's Reservoir near Weiner and other large bodies of water and rivers during late fall, winter and spring. The Bald Eagle was observed once during a spring roadside survey near Corning, Arkansas (Table 1).

The Red-shouldered Hawk is an uncommon permanent resident which nests on Crowley's Ridge and also in wooded areas near Corning in Randolph and Clay Counties. Cooper's Hawks probably nest at Wapanocca and other sufficiently wooded areas of the delta as well as in the Ozarks. Only five records exist for the Sharp-shinned Hawk from the northeastern delta region and Crowley's Ridge. Four of these were in the fall or winter and one was in the spring from Greene County on Crowley's Ridge. The Merlin *(Falco columbarius)* is also

Table 1. Seasonal hawk populations in northeastern Arkansas (1974-1977).

Month	Miles traveled	Total hawks per 100 mi.	Turkey Vulture	Cooper's Hawk	Red-tailed Hawk	Red-shouldered Hawk	Broad-winged Hawk	Rough-legged Hawk	Marsh Hawk	American Kestrel	Bald Eagle	Merlin
			Hawks per 100 miles									
Sept.	1913	1.20	-	-	0.57	-	0.05	-	-	0.57	-	0.12
Oct.	1509	5.43	-	0.07	3.24	-	-	-	0.07	2.05	-	0.15
Nov.	1963	15.91	0.10	0.15	10.53	-	-	-	1.19	3.87	-	-
Dec.	2142	20.68	-	-	6.30	-	-	0.42	2.19	11.76	-	-
Jan.	3877	7.69	-	0.05	3.56	0.05	-	0.02	0.85	3.02	-	-
Feb.	2519	17.31	0.20	-	8.65	0.03	-	0.15	1.59	6.47	-	-
Mar.	3027	5.72	0.17	-	3.20	-	-	0.03	0.39	1.92	-	-
Apr.	3224	1.99	0.34	-	0.37	0.03	0.03	-	-	1.18	0.03	-
Total	20,174	1819*	22	6	864	4	2	15	156	745	1	4

*Values in this line represent total hawks seen during study period, not total hawks per 100 miles of highway travel.

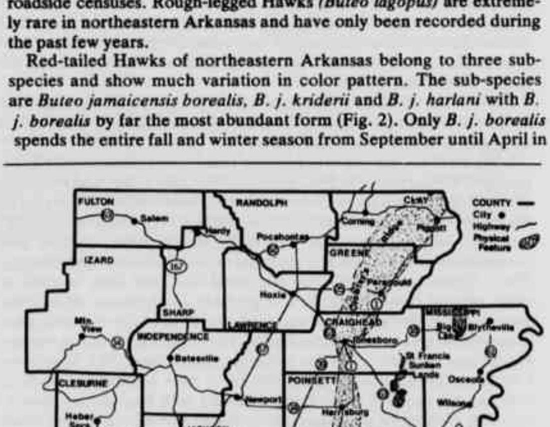

Figure 1. Map of counties of northeastern Arkansas included in the census area. Only the major highways are illustrated.

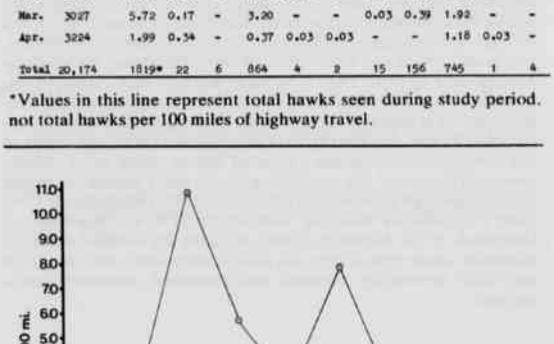

Figure 2. Seasonal occurrence of *Buteo jamaicensis borealis, B. j. harlani* and *B. j. kriderii* in northeastern Arkansas. The data on *B. j. harlani* probably also includes data on immature *B. j. borealis* which are indistinguishable from the *harlani* morph in the field.

extremely rare in northeastern Arkansas. Few have been observed during the past 15 years although two were seen during Christmas bird counts (Table 2), and nine were recorded during the roadside surveys.

The Mississippi Kite, a summer resident along the Mississippi River in northeastern Arkansas, has been found nesting in the tall cottonwoods *(Populus deltoides)* along the highway in Wilson, Arkansas, during recent breeding bird censuses. This species is also common near Luxora, Arkansas, and has been observed in May for the past two years at Wapanocca where it probably nests.

Hawks begin to appear in mid-September and reach their highest numbers in December (Fig. 3). The numbers then drop in January apparently because the hawks migrate further south in response to the colder weather around the first of the year. Populations reach a second peak in February and then decline through April (Fig. 3). Red-tailed Hawks, American Kestrels and Marsh Hawks comprise the bulk of the raptors during the winter season (Fig. 4). The Red-tailed Hawk peaks in November and declines through January, while the American Kestrel and the Marsh Hawk peak in December and also drop in January. All three species reach a second peak in February. The Marsh Hawk migrates out of the region in March, followed by the Red-tailed Hawk in April and the American Kestrel by 1 May, after which only a few permanent residents remain. The latest seasonal record of the Marsh Hawk in northeastern Arkansas that the senior author has is 16 April 1976 near Corning in Clay County. As previously stated though, most are gone by the end of March. Red-tailed Hawks do nest in this region but so sparingly that they are not usually seen from the roadside.

Long Term Trends in Hawk Populations:

Although environmentalists have been highly critical of habitat destruction and insecticide pollution, Christmas bird count records for 1967 through 1976 do not show any general decline in hawk populations (Table 2) as determined by a single sample runs test (Seigel, 1956). Population fluctuations of the three most abundant species, Red-tailed Hawk, American Kestrel and Marsh Hawk, however, do show significant yearly differences ($X^2=62.41$, df=2, $p<.001$) (Fig. 5). A review of the literature on relative abundance of hawk species in the late 1880's and early 1900's (Pindar, 1924, and Hollister, 1902) shows little or no change compared to today's listings. Although Pindar's surveys were made in 1888-1889 they were not published until 1924.

A comparison of Figures 4 and 5 reveals an apparent discrepancy in the values for Marsh Hawk and American Kestrel. Roadside surveys show the American Kestrel to be the second most abundant hawk species while the Christmas bird count data show the Marsh Hawk to be second in abundance. The Christmas bird count values probably more closely represent the true values for the Marsh Hawk. During a Christmas bird count there are usually at least two people in the party, one to drive and at least one to observe, so the more elusive Marsh Hawk is likely to be seen flying low over the fields. Also, many are probably flushed by observers on foot whereas a single person driving down the highway is likely to miss this low flying species particularly since Marsh Hawks do not usually perch on elevated objects.

Red-tailed Hawks are not evenly distributed in northeastern Arkansas but seem to follow rice production. The highest numbers are

Table 2. Ten year summary of annual Christmas Bird Counts for Jonesboro, Arkansas.

Hawk species	Year '67	'68	'69	'70	'71	'72	'73	'74	'75	'76	Total per species
Cooper's Hawk	0	0	0	0	3	1	0	0	0	0	4
Sharp-shinned Hawk	0	0	0	0	0	0	0	0	1	0	1
Red-tailed Hawk	64	20	24	16	32	26	19	47	31	38	317
Red-shouldered Hawk	1	2	1	0	0	0	0	0	1	2	7
Rough-legged Hawk	0	0	0	0	0	0	0	0	1	0	1
Marsh Hawk	67	18	31	13	15	23	18	12	24	13	234
Merlin	1	0	0	0	1	0	0	0	0	0	2
American Kestrel	11	13	12	20	18	17	9	20	16	22	158
Total per year	144	53	68	49	69	67	46	79	72	75	724

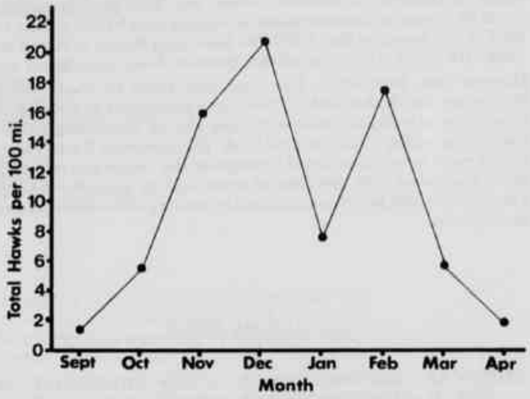

Figure 3. Total seasonal raptor population numbers for the winter season (September through April). Values indicated are number of hawks per 100 miles of highway travel.)

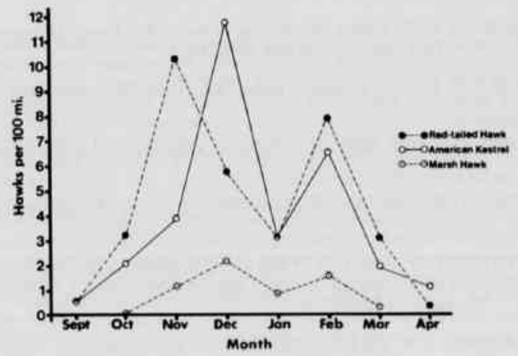

Figure 4. Seasonal population trends for the Red-tailed Hawk, American Kestrel and Marsh Hawk. (Values indicated are numbers of hawks per 100 miles of highway travel.)

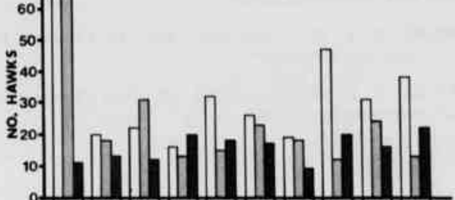

Figure 5. Winter hawk population trends based on Jonesboro Christmas Bird Count records for 1967 through 1976. Only the three most abundant species, the Red-tailed Hawk, Marsh Hawk and American Kestrel, are shown.

found on Highway 39 between Gibson and Brinkley. This pattern could be related to concentrations of rodents used by the species for food as was found by Bart (1977) for Red-tailed Hawks in New York State. He found a high correlation between hawk populations and *Microtus* spp. abundance. The same may apply to Marsh Hawk distribution which also tends to follow rice production in this region. In addition to rodents, this species may also be responding to bird populations which it also uses for food. The American Kestrel however is more evenly distributed throughout this region and is usually found associated with any type of open field or agricultural crop. These distribution patterns are indeed interesting and deserve further investigation.

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Fishes of the Mountain Province Section Of the Ouachita River

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ABSTRACT

A survey of the fishes of the mountain province section of the Ouachita River from the headwaters to Remmel Dam using field collections, literature records, and museum collections showed the ichthyofauna to be made up of 80 species representing 16 families. Fourteen species not previously reported from the mountain province section of the river were collected in this survey. These species include *Ichthyomyzon gagei, Nocomis asper, Notropis ortenburgeri, N. rubellus, Pimephales promelas, Moxostoma carinatum, Noturus taylori, Fundulus notatus, Lepomis humilis, Etheostoma histrio, E. proeliare, Percina maculata, P. nasuta*, and *P. uranidea*. The *Nocomis* specimens were the first collected from the Ouachita River system and the discovery of *Noturus taylori* represents a major range extension.

INTRODUCTION

The Ouachita River arises in Polk County in west-central Arkansas, flows in a southeasterly direction through 11 counties in Arkansas, six parishes in Louisiana, and enters the Red River approximately 35 miles above the confluence of the Red and Mississippi Rivers. The 605 mile length of the Ouachita River drains an area of approximately 24,790 square miles. Markham (1935) divided the river into three distinct provinces based on the type of terrain. These provinces were the alluvial lowland province, the hill province, and the mountain province. The mountain province section encompasses approximately 10 per cent of the total area drained.

Douglas (1974) included a comprehensive survey of the fishes of the Ouachita River in Louisiana while Raymond (1975) surveyed the fishes of the hill province section from Remmel Dam on Lake Catherine to the Arkansas-Louisiana line. In an effort to complete ichthyological survey work on the Ouachita River, the authors undertook a thorough investigation of the fishes of the mountain province section from the headwaters to Remmel Dam on Lake Catherine, the last major unsurveyed section of the Ouachita River proper.

Apparently Meek (1891) was the first to investigate the headwaters of the Ouachita River and its tributaries which he described as "swift, flowing streams of clear water with rock and gravel bottoms." He reported 30 species collected from the South Fork of the Ouachita River near Mt. Ida, Montgomery County, Arkansas; and three localities in Garland County, Arkansas: the Ouachita River near Crystal Springs, Mazarn Creek, and Myers Creek. Hubbs and Ortenburger (1928) sampled several tributaries of the Ouachita River in Polk County, Arkansas, collecting 12 species. These typical headwater streams were composed of alternate pools and riffles with clear water and a substrate of large rocks, gravel, and sand. Black (1940) and Buchanan (1973) added additional information on the fish fauna known to occur in the mountain province of the Ouachita River. Robison (1974) reported the presence of *Etheostoma pallididorsum* in the mountain province of the Ouachita River. *E. pallididorsum* was previously considered endemic to the Caddo River system.

The following report is based upon collections made by Meek (1891); Hubbs and Ortenburger (1928); Dr. Henry W. Robison, Southern Arkansas University; the Arkansas Game and Fish Commission (AGFC); the University of Tennessee Regional Faunas class; the authors; and from collections housed at Tulane University and Northeast Louisiana University.

DESCRIPTION OF THE AREA

The survey area from the headwaters of the Ouachita River to Remmel Dam on Lake Catherine is approximately 90 miles in length and drains a watershed of approximately 1,516 square miles (J. E. Henley, pers. comm.) in Polk, Montgomery, Garland, and Hot Spring Counties (Fig. 1). The majority of the land drained by the Ouachita River in the mountain province section consists of mixed loblolly pine, shortleaf pine, and hardwood forests, with a small section of pure hardwood forests in Garland County. The soils in the area are mainly silty clay and silty loam with shale, sandstone, novaculite, and quartzite the common surface rocks (Foti, 1974). The extreme headwaters consist of clear rock bottom pools connected by shallow riffles and offer little habitat diversity. Stream conditions change gradually downstream as moderate or fast flowing waters cover rock, gravel, and sand substrates, and deeper pool situations become more common, offering greater habitat diversity. As the river approaches the lakes region, the water becomes less swift and more turbid, and sandy substrates become more common.

A large portion of the mainstream of the mountain province section has been altered by human activity. Three reservoirs have been constructed in the lower portion of the study area where the river once flowed unimpeded. Lakes Catherine and Hamilton were constructed in 1925 and 1932, respectively, for industrial purposes by Arkansas Power and Light Company. Lake Ouachita, the largest lake, is a federal reservoir completed in 1954. The upper half of the study area is predominately rural and remains virtually unaltered.

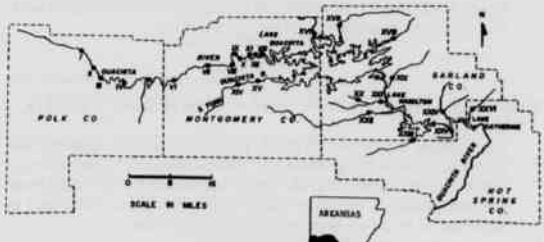

Fig. 1. Map of the mountain province section of the Ouachita River, with collecting locations.

METHODS

Most collections were made with seines of 3/16" mesh measuring 4 x 5', 8' x 10', and 8' x 20', but on several occasions, ¼" mesh seines measuring 8' x 30' and 10' x 40' were used. Collections made by the Arkansas Game and Fish Commission (AGFC) utilized gill nets, trammel nets, and rotenone. Specimens were preserved in 10 percent formalin solution in the field before being placed in 40 per cent isopropanol for permanent storage. Representative specimens are housed in the collection of fishes at Southern Arkansas University, Tulane University, University of Tennessee, and the Museum of Zoology at Northeast Louisiana University. Nomenclature follows Bailey *et al* (1970).

ANNOTATED LIST OF THE FISHES OF THE MOUNTAIN PROVINCE SECTION OF THE OUACHITA RIVER

Roman numerals following the species name indicate localities where the species was collected (Fig. 1).

Petromyzontidae (Lampreys)

Ichthyomyzon castaneus Girard. Chestnut lamprey. V, VI
Uncommon inhabitant of the mainstream of the river and larger tributaries. AGFC reported *I. castaneus* from L. Hamilton.

I. gagei Hubbs and Troutman. Southern brook lamprey. VI
Uncommon; collected from mainstream in swift water during early spring.

Lepisosteidae (Gars)

Lepisosteus oculatus (Winchell). Spotted gar. VIII
A common inhabitant of the deep, slow-moving pools of the river and the lakes.

L. osseus (Linnaeus). Longnose gar.
More common in the lakes but also found in the deeper pools of the main river.

Clupeidae (Herrings)

Dorosoma cepedianum (Lesueur). Gizzard shad. XIII
An abundant inhabitant of the lakes, *D. cepedianum* is also common in the lower portion of the main river and larger tributaries to the lakes.

D. petenense (Gunther). Threadfin shad. XII, XIII
Like *D. cepedianum*, abundant in the lakes and common in the lower river and larger tributaries of the lakes.

Salmonidae (Salmons)

Salmo gairdneri Richardson. Rainbow trout. XXV
Stocked in the lakes for the past 10-15 years by the AGFC to accommodate sport fishermen. Reproducing populations may occur in the colder tributaries of the lakes, but for the most part, this species is maintained in lakes by stocking.

Esocidae (Pikes)

Esox americanus vermiculatus Lesueur. Grass pickerel. I, III, XIX, XX
Uncommon inhabitant of large, permanent pools characterized by clear, slow-moving water and an abundance of aquatic vegetation. It was collected in the upper headwaters of the main river and tributaries of the lakes where these conditions occur and is expected to be a common inhabitant of the lakes.

E. niger Lesueur. Chain pickerel. III, XVIII
Exhibits the same habitat preferences as *E. americanus vermiculatus*. It is also expected to occur in the upper headwaters of the main river, tributaries of the lakes, and the shallower waters of the lakes.

Cyprinidae (Minnows)

Campostoma anomalum (Rafinesque). Stoneroller. I, III, IV, V, VI, VII, VIII, IX, X, XI, XII, XIV, XV, XVII, XVIII, XIX, XX, XXI, XXII, XXIII, XXIV, XXVI
Common and widespread throughout the study area, especially in shallow pools and gravel bottom riffles.

Ctenopharyngodon idella (Valenciennes). Grass carp.
Introduced into the lakes in the early 1970's by AGFC in an effort to control aquatic plant growth.

Cyprinus carpio Linnaeus. Carp.
Collected from the lakes by AGFC and expected to occur in sluggish, deep portions of the river.

Hybopsis x-punctata Hubbs and Crowe. Gravel chub. VIII, IX, XI
Uncommon cyprinid probably restricted to the mainstream of the river in areas of permanent flow, gravel bottom, and well-defined riffles.

Nocomis asper Lachner and Jenkins. Redspot chub. XIV, XV
First member of its genus reported from the Ouachita River system. It was collected only from the South Fork of the Ouachita River in gravel bottom pools, 2-6 feet deep, with clear water and moderate flow.

Notemigonus crysoleucas (Mitchell). Golden shiner. V, IX, XI, XIII, XV
The most commonly sold baitfish in the study area, it is an uncommon inhabitant of the mainstream of the river and lakes, where it is undoubtedly constantly introduced through bait release.

Notropis amnis Hubbs and Greene. Pallid shiner.
Not collected by the authors but reported from the lakes in AGFC records.

N. atherinoides Rafinesque. Emerald shiner.
Not collected by the authors but reported from the lakes in AGFC records.

N. boops Gilbert. Bigeye shiner. I, II, III, IV, V, VI, VII, VIII, IX, X, XI, XII, XIII, XIV, XV, XVI, XVII, XVIII, XIX, XXI, XXIII, XXIV, XXV, XXVI
Probably the most abundant fish in the study area, it is widespread and was found in a variety of habitats.

N. chrysocephalus isolepis Hubbs and Ortenburger. Southern striped shiner. I, II, III, IV, V, VI, XIV, XV, XVII, XIX, XX, XXI, XXII, XXIII, XXIV, XXV, XXVI
Common inhabitant of clear pools in the upper portions of the main river and tributaries of the lakes. A conspicuous absence from the larger lower portion of the main river would seem to indicate a preference for smaller, less turbid waters.

N. fumeus Evermann. Ribbon shiner.
Not collected by the authors but reported from the lakes by AGFC records.

N. ortenburgeri Hubbs. Kiamichi shiner. I
Collected from a single location in the headwaters of the main river in clear, deep pools with rocky bottoms and is considered uncommon.

N. perpallidus Hubbs and Black. Colorless shiner. IV, V, VIII, X
Uncommon inhabitant of the mainstream of the river in water 2-4 feet deep with slow to moderate current. Most specimens were found associated with habitat that included *Justicia americana* and a rock and sand substrate as indicated by Snelson and Jenkins (1973).

N. rubellus (Agassiz). Rosyface shiner. IV, V, VI, VII, VIII, IX, X, XI, XII
A common inhabitant of the mainstream of the river near riffles or in pools with moderate current and a gravel or rock substrate. It seems to avoid the extreme headwaters and high gradient tributaries.

N. umbratilus (Girard). Redfin shiner. I, II, III, IV, V, VI, VII, VIII, IX, X, XI, XII, XIII, XIV, XV, XVI, XVII, XVIII, XIX, XXII, XXIV, XXV, XXVI
An abundant species distributed throughout the study area, showing a preference for pool areas with clear water and little flow.

N. whipplei (Girard). Steelcolor shiner. III, IV, V, VI, VII, VIII, IX, X, XI, XII, XIII, XIV, XV

Appears limited to the larger, faster flowing waters of the mainstream and the South Fork of the river near rocky riffles in fast or moderate current. It was abundant at most locations where it was collected.

Opsopoeodus emiliae Hay. Pugnose shiner. III, IV, V, XII, XIII
An uncommon inhabitant of the study area collected from quiet pools and backwater areas along the mainstream of the river; also expected to occur in the shallower portions of the lakes.

Pimephales notatus (Rafinesque). Bluntnose minnow. I, II, III, IV, V, VI, VII, VIII, IX, X, XI, XII, XIII, XIV, XV, XVIII, XXIII, XXIV, XXV, XXVI
Widespread and common throughout the study area, with a preference for pool areas with rocky or sandy bottoms and a moderate flow.

P. promelas Rafinesque. Fathead minnow. IV, V
Uncommon and probably introduced into the study area through bait release.

P. tenellus (Girard). Slim minnow. IV, VI, VI, VIII, IX, X, XI, XII, XIII
Much less common than *P. notatus* and seemingly restricted to the mainstream of the river in pools with moderate current and rock and sand substrate.

P. vigilax (Girard). Bullhead minnow.
Reported by Hubbs and Ortenburger (1928) from a single specimen in the extreme headwaters. None were collected by the authors during this study.

Semotilus atromaculatus (Mitchill). Creek chub. XX
An uncommon inhabitant of small headwater creeks where few other species occur.

Catostomidae (Suckers)

Erimyzon oblongus (Mitchill). Creek chubsucker. VI, XV
An uncommon inhabitant of the smaller tributaries in the study area, collected from sluggish pools having clear water, sand and gravel bottoms, and an accumulation of organic debris.

Hypentelium nigricans (Lesueur). Northern hog sucker. IV, V, VI, VIII, IX, XI, XII, XIII, XIV, XXIV, XXV, XXVI
A common inhabitant of the main river and lake tributaries in areas of permanent flow and rock bottom.

Ictiobus cyprinellus (Valenciennes). Bigmouth buffalo.
AGFC records indicate a single specimen collected January, 1971, just above Remmel Dam on Lake Catherine.

Minytrema melanops (Rafinesque). Spotted sucker. III, XIII, XV, XXVI
Widely distributed but uncommon within the study area. Most often collected from deep backwater areas of the river and lake tributaries with little flow and abundant organic debris.

Moxostoma carinatum (Cope). River redhorse. XII
Uncommon and restricted to the deeper pools of the river with strong flow.

M. duquesnei (Lesueur). Black redhorse. IV, VII, VIII, IX, X, XI, XII, XIII, XIV, XV, XXII
A common and widespread inhabitant of the study area in both shallow and deep pools.

M. erythrurum (Rafinesque). Golden redhorse. III, IV, VIII, IX, XIII, XV, XXV, XXVI
Like *M. duquesnei*, common and widespread in the study area. It was found in more slowly-moving water than the other members of its genus.

Ictaluridae (Catfishes)

Ictalurus furcatus (Lesueur). Blue catfish.
Periodically stocked by the AGFC in the lakes. Expected to occur in deeper waters of the river.

I. melas (Rafinesque). Black bullhead. XIII
Uncommon ictalurid confined to the lakes and portions of the main river and lake tributaries with little flow and a silt substrate.

I. natalis (Lesueur). Yellow bullhead. I, V, VIII, XII, XIX, XXI, XXIV
A widespread but uncommon inhabitant of the study area collected from the slow-moving, deeper pools but showed more tolerance to current than did the black bullhead.

I. punctatus (Rafinesque). Channel catfish. V, VII, VIII, XII
Reported throughout the mainstream of the river and stocked annually in large numbers in the lakes.

Noturus gyrinus (Mitchill). Tadpole madtom. XXIV
The least abundant member of the family Ictaluridae, probably restricted to lake tributaries having moderate current and thick growths of aquatic vegetation or heavy accumulations of organic debris.

N. nocturnus Jordan and Gilbert. Freckled madtom. IV, V, VI, VII, VIII, IX, XI, XII, XVI, XIX, XXII
A common inhabitant of the upper mainstream of the river in riffle areas with heavy growths of aquatic vegetation. Much less common in the lower river and lake tributaries.

N. taylori Douglas. Caddo madtom. IV, V, VIII, XI, XII, XIII, XV
Although previously considered endemic to the Caddo River system, it was collected from seven locations on the mainstream and South Fork of the Ouachita River. Collected most often at night from pool areas with moderate flow and sandy substrate, although it was occasionally taken from rocky riffles with fast flow.

Aphredoderidae (Pirate perches)

Aphredoderus sayanus (Gilliams). Pirate perch. XIX, XX
Restricted to the lower portion of the study area near the lakes in backwaters having clear, warm water, absence of current and abundant aquatic vegetation or organic debris.

Cyprinodontidae (Topminnows)

Fundulus catenatus (Storer). Northern studfish. IV, V, VI, VIII, IX, XI, XII, XIII, XIV, XV, XVII, XVIII, XIX, XX, XXI, XXIV, XXV, XXVI
Common and widespread throughout the study area. Most often found in shallow inlets away from swift current.

F. notatus (Rafinesque). Blackstripe topminnow. XX, XXVI
Uncommon species collected only from tributaries of the lakes in slow-moving pools or backwater areas.

F. olivaceus (Storer). Blackspotted topminnow. I, II, III, IV, V, VII, VIII, IX, X, XI, XII, XIII, XV, XIX, XX, XXII, XXV, XXVI
The most widely distributed topminnow collected and is expected to occur throughout the study area.

Poeciliidae (Mosquitofishes)

Gambusia affinis (Baird and Girard). Mosquitofish. IV, V, VI, VIII, X, XIII, XIX, XXI, XXII, XXIV
Widespread but common only in the sluggish lower portion of the main river, but it is expected to be more numerous in the lakes.

Atherinidae (Silversides)

Labidesthes sicculus (Cope). Brook silverside. I, II, III, IV, V, VI, VII, VIII, IX, X, XI, XII, XIII, XIV, XV, XVI, XVII, XIX, XXI, XXII, XXIV
An abundant inhabitant of the study area.

Percichthyidae (Temperate basses)

Morone chrysops (Rafinesque). White bass.
Reported by AGFC from the lakes and by local fishermen from the river.

M. saxatilis (Walbaum). Striped bass. V
First introduced into Lake Ouachita in the late 1950's. During recent years it has been stocked into all three lakes in large numbers and occurs in the mainstream of the river.

Centrarchidae (Sunfishes)

Ambloplites rupestris (Rafinesque). Rock bass. VI, VIII, XI, XII, XIX
An uncommon inhabitant of the main river and larger lake tributaries, found most often in pool areas with abundant aquatic vegetation.

Lepomis cyanellus Rafinesque. Green sunfish. I, II, III, IV, V, VI, VII, VIII, IX, XI, XII, XIV, XV, XVI, XVII, XIX, XX, XXII, XXIV
Uncommon but widely distributed throughout the study area and expected to be common in the lakes.

L. gulosus (Cuvier). Warmouth. III, XIII
Collected from backwater pools of the main river having abundant organic debris and from the lakes; very uncommon.

L. humilis (Girard). Orangespotted sunfish. IV
Collected from a single sandy bottom pool with moderate flow in the upper portion of the main river.

L. microlophus (Gunther). Redear sunfish. II, VII, XII, XIII, XXIV
Uncommon but widely distributed in quiet pools along the main river, larger tributaries and the lakes.

Micropterus dolomieui Lacepede. Smallmouth bass. I, V, VI, VII, XII, XIII, XXII
Uncommon and restricted to the mainstream of the river and larger lake tributaries in pools with moderate flow and clear rock or sand bottom.

M. punctulatus (Rafinesque). Spotted bass. I, II, III, IV, V, VI, VII, VIII, IX, XI, XII, XIII, XIV, XV, XIX, XXI, XXII
The most common and widely distributed member of its genus within the study area.

M. salmoides (Lacepede). Largemouth bass. I, III, V, VI, XXIV
The largemouth bass is stocked annually by the AGFC in the lakes. It was occasionally collected from the mainstream of the river.

Pomoxis annularis Rafinesque. White crappie. IV, XIII
Common in the lakes and deeper pools of the main river.

P. nigromaculatus (Lesueur). Black crappie.
Reported from the lakes by the AGFC.

Percidae (Perches)

Etheostoma blennioides Rafinesque. Greenside darter. I, IV, V, VI, VII, VIII, IX, X, XI, XII, XIV, XV, XVI, XVII, XVIII, XIX, XX, XXI, XXII, XXIV
Common throughout the main river and lake tributaries where it was collected from a variety of habitats. Adults were taken from deep, rocky riffles with swift current while juveniles were taken from pools with moderate flow and aquatic vegetation.

E. chlorosomum (Hay). Bluntnose darter. XIII
Collected only at the confluence of the Ouachita River and Lake Ouachita in slow-moving water with a sandy substrate although it may occur in the lakes near the confluence of tributaries.

E. collettei Birdsong and Knapp. Creole darter. XV, XIX, XXIV, XXVI
Uncommon and restricted to lake tributaries in shallow, rocky riffles with moderate to fast current.

E. histrio Jordan and Gilbert. Harlequin darter. XII
Uncommon; was collected from a single location in the lower portion of the main river from a shallow riffle with rock and sand substrate and moderate flow.

E. nigrum Rafinesque. Johnny darter. I, IV, V, VIII, XI, XII, XIII, XV
Uncommon and limited in distribution to the mainstream and South Fork of the Ouachita River. Found in quiet pools with clean sand and gravel bottoms.

E. pallididorsum (Distler and Metcalf). Paleback darter. XX
Previously considered endemic to the Caddo River system, it is apparently restricted to Mayberry Creek within the mountain province section of the Ouachita River and is extremely uncommon (Robison, 1974).

E. proeliare (Hay). Cypress darter. XIX
Specimens were collected from Glazypeau Creek in shallow pools with no flow and heavy aquatic vegetation consisting of *Myriophyllum heterophyllum* and algae.

E. radiosum (Hubbs and Black). Orangebelly darter. I, II, III, IV, V, VI, VII, VIII, IX, X, XI, XII, XIII, XIV, XV, XVI, XVII, XVIII, XIX, XXI, XXII, XXIII, XXIV, XXVI
The most common and widely distributed member of its genus within the study area.

E. stigmaeum (Jordan). Speckled darter. IV, VI, VIII, XI, XII, XIII, XV
Parallels *E. nigrum* very closely in distribution and relative abundance in the study area. Both seem limited to the upper half of the study area and are more common in the slower, sandy bottom portions of the lower main river.

E. zonale (Cope). Banded darter. IV, V, VI, VII, VIII, IX, X, XI, XII, XIV, XV, XXII
Common in the upper half of the study area in rocky riffles of the mainstream and South Fork of the river.

Percina caprodes (Rafinesque). Logperch. VI, VIII, IX, XI, XII, XIII, XV, XIX, XXI, XXII, XXIV, XXV
Widely distributed and moderately common. Most often collected from depressions in rock bottom or sandy bottom pools in the mainstream of the river and lake tributaries.

P. copelandi (Jordan). Channel darter. IV, V, VI, VIII, IX, X, XI, XII, XIII, XV, XIX, XXI, XXII
Most common member of its genus within the study area. Collected most frequently from sluggish riffles and sandy bottom pools in the mainstream of the river and lake tributaries.

P. maculata (Girard). Blackside darter. V
A single specimen was collected from a slow-moving portion of the main river with rock and sand bottom during the spring of the year.

P. nasuta (Bailey). Longnose darter. V, VI, VIII, IX, XI, XIII
The longnose darter appears to be uncommon and seasonal in its habitat selection throughout the mainstream of the river. Specimens collected during the spring of the year were in fast, deep riffle areas with rocky substrate and thick growth of *Podostemon heterophyllum*. The single specimen taken during the fall was collected from a sluggish silt bottom pool at the confluence of the river and Lake Ouachita.

P. uranidea (Jordan and Gilbert). Stargazing darter. XI, XII
Uncommon and apparently restricted to the main river. Two specimens were collected at night in fast, deep riffle areas with gravel and rock substrate.

Stizostedion vitreum (Mitchill). Walleye.
Stocked into the lakes by AGFC, the walleye is reported common in the lower portions of the main river during the spring months.

Sciaenidae (Drums)

Aplodinotus grunniens Rafinesque. Freshwater drum.
Collected from the lakes by the AGFC.

DISCUSSION

The known ichthyofauna of the mountain province of the Ouachita River is represented by 80 species distributed among 16 families. Another species was reported in the literature but is of questionable status. Meek (1891) reported *Chrosomus (Phoxinus) erythrogaster* from the South Fork of the Ouachita River near Mt. Ida. This species has not been reported since from the Ouachita River drainage. If it did occur, it probably has been eliminated from the study area, or perhaps its inclusion in the literature is the result of misidentification.

Nocomis asper was the first member of its genus reported from the Ouachita River drainage (Douglas and Harris, 1977). Within Arkansas, it was previously considered restricted to the Arkansas River drainage in the northwest corner of the state. The occurrence of *N. asper* within the Ouachita River drainage is not easily explained. Bait release and faunal exchange between the Arkansas and Ouachita River drainages are possibilities that are considered unlikely. A more plausible explanation is that the Ouachita River population is a disjunct relict much like three isolated populations of *N. asper* in Oklahoma (two in the Red River drainage and one in the White River drainage) reported by Lachner and Jenkins (1971).

Noturus taylori was considered endemic to the Caddo River system prior to this study (Douglas, 1972). *N. taylori* was collected from seven stations in the mainstream and South Fork of the Ouachita River. It is hypothesized that *N. taylori* evolved in the Caddo system, migrated via lateral stream transfer and capture to the mountain province section, and has since established a reproducing population there. The distribution and biogeography of *N. taylori* is being treated more fully by Robison and Harris (in press).

Fourteen of the 80 species now known from the mountain province of the Ouachita River had not been reported previous to this study. These species include: *Ichthyomyzon gagei, Nocomis asper, Notropis ortenburgeri, N. rubellus, Pimephales promelas, Moxostoma carinatum, Noturus taylori, Fundulus notatus, Lepomis humilis, Etheostoma histrio, E. proeliare, Percina maculata, P. nasuta,* and *P. uranidea.*

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Taste-Masking: A Function of Exaggerated Prandial Drinking in Desalivate Mice

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ABSTRACT

Taste thresholds for the bitter compound sucrose octaacetate (SOA) were elevated by desalivation in mice. Thresholds were determined for control and experimental animals both before and after ligation of all salivary ducts. There was a significant increase in SOA thresholds in the desalivate mice, and the pre- to post-operative differences in threshold between the control and experimental groups were significant.

The altered response to SOA by desalivate mice is shown to be due to the assumption of a prandial pattern of drinking as a result of desalivation. This conclusion is based on experiments with wet mash which failed to show any differences in threshold between the same control and desalivate mice that demonstrated a significant difference when tested on fluids and dry pellets.

INTRODUCTION

Vance (1965) demonstrated an elevated rejection threshold to quinine hydrochloride (QHC1) in desalivate rats, and suggested a salivary influence on taste receptors to be responsible for the difference in threshold.

To appreciate the significance of changes in taste aversion after ligation of the salivary ducts, it is important to consider coincident changes in the temporal patterning of feeding and drinking. Preventing saliva from reaching the oral cavity, either by removing the salivary glands (Epstein *et al.*, 1964) or by ligating the salivary ducts (Vance, 1965; Kissileff and Epstein, 1969), results in a modification of nutritive behavior in the rat and has been described as prandial drinking (Teitelbaum and Epstein, 1962). Prandial drinking is characterized by small droughts of water being consumed immediately after a morsel of dry food is taken into the mouth (Kissileff and Epstein, 1969). Vance (1965) proposed that desalivate rats use their drinking water as an exogenous saliva to permit the swallowing of dry food, a view clearly supported by Kissileff (1969b).

The present study demonstrates that desalivate mice also assume a prandial pattern of drinking which is consistent with the descriptions of this behavior in desalivate rats. Small draughts of water are alternated with short feeding episodes, the durations of each of these activities consisting of only a few seconds. It is suggested that the difference in threshold between control and desalivate animals is due to a "masking effect" related to the prandial drinking pattern assumed by the desalivate animal as originally proposed by Lewis and Warren, (1969). The masking hypothesis is based on two assumptions: one, that desalivate mice and rats use their drinking water as an exogenous saliva to permit the swallowing of dry food; and two, that the great majority of drinking bouts occur in close temporal association with feeding. Under the conditions, the taste of any compound in the drinking water would be masked by having it compete simultaneously with the taste of food in the mouth which was being softened into a mash to permit swallowing.

This study employed the aversive substance sucrose octaacetate (SOA) and tested the hypotheses of Vance (1965) and Lewis and Warren (1969) by eliminating the differences in nutritive behavior between normal and desalivate mice by the use of a wet mash. The effect of the absence of saliva on rejection thresholds could then be assessed without the interference that may be contributed by behavioral differences.

MATERIALS AND METHODS

Threshold determinations were made by employing paired 25 ml burettes in a modified 24-hour choice test. Over any four-day period, the burettes would be rotated daily in a LRRL manner, while the test solution was rotated LRLR. The effect of this rotation scheme was the presentation for a 24-hour period of each of the four possible combinations of side and burette for the test solution and the water it was paired with. By this means, the biasing of threshold data by side or burette preference was avoided. The test solution was presented in an ascending series by increasing the concentration every two days by about one-third of a log molar step. For example, the sequence of SOA concentrations used was $6x10^{-7}$M, $1.5x10^{-6}$M, $3x10^{-6}$M, $6x10^{-6}$M, etc. Rejection was defined as that concentration of SOA at which its intake constituted less than 30% of the total fluid consumption over a 48-hour period. Lab Blox food pellets were available *ad libitum*.

Special cages with two food cups attached were employed for the wet mash experiments. The food cups were located at the end of short runways attached to one wall of the cage. The cups were filled each day with mash prepared by mixing food pellets, which were ground to a powder, with water (or SOA solution) in the ratio of 35 grams of dry food for every 65 ml of solution. The concentration of test solution used to make the test mash was increased every two days, and the position of the test mash was alternated with the control mash daily. The mouse then had a two-cup, 24-hour choice situation essentially identical in method to the tests with burettes. The amount of mash consumed from each cup was determined by weighing the cup when filled and again after the 24-hour feeding period. Rejection was defined as that concentration of SOA at which the SOA mash constituted less than 30% by weight of the total mash consumption for the 24-hour period.

All animals were tested for frequency and duration of feeding and drinking episodes on burettes both before and after desalivation. Data was recorded for a 30-minute test period which was preceded by 16-20 hours of food and water deprivation. Drinking was monitored both for duration and frequency by means of an Esterline-Angus event recorder, while feeding episodes were observed and noted on the drinking record.

Desalivation was performed by ligating all six salivary ducts with silk thread (size 000) through a 2 cm incision in the throat. A suturing needle was used to pass the thread beneath the ducts to minimize damage to surrounding tissues.

Sixteen F_1 progeny of C_57B1/6 and CFW mice were tested to rejection on sucrose octaacetate (SOA) by means of burettes. Drinking and feeding patterns were then assessed for all animals in a 30-minute test period following 16-20 hours of food and water deprivation. Nine of the 16 mice were desalivated, and upon their recovery, all animals were again tested to rejection on SOA as in the pre-operative test. Following this post-operative threshold test, nutritive behavior was again monitored in a 30-minute test as before to detect and record differences due to desalivation. In each case, the assessment of feeding and drinking behavior was carried out immediately after testing for SOA rejection thresholds to elucidate any behavioral differences that may have existed between the mice on the pre-operative and post-operative threshold determinations with burettes. Lastly, a third and final threshold determination for SOA was performed, this time comparing the control and desalivate groups by means of a wet mash.

RESULTS

As can be seen in Table I, in only the second of the three threshold determinations on SOA is there a significant difference in consumption. This marked increase in fluid consumption by desalivate mice is paralleled by a modification of nutritive behavior as indicated in Table II. Although desalivate mice show a marked alteration in drinking when eating dry lab pellets, the differences in nutritive behavior between desalivates and controls disappear in mice eating wet mash. In the wet mash experiment no differences could be detected in amount of mash consumed or SOA thresholds between the two groups.

Table II is consistent with what would be expected if desalivate mice responded to dry food as has been described for desalivate rats. The most important of these measures in terms of the masking hypothesis, however, are those concerned with the temporal relationship of feeding and drinking. It can be seen that 70% of all drinking bouts by desalivate mice occurred within five seconds of the end of a feeding episode, whereas in the controls and the experimental group (before desalivation) no drinking bouts occurred this close to a feeding episode.

DISCUSSION

Desalivation in mice brings about essentially the same changes in nutritive behavior (prandial drinking) as has been described for desalivate rats (Kissileff 1969a). In each case, a desalivated animal shows a marked increase in water consumption when it is eating dry food (Epstein *et al.*, 1964). This is due to the desalivate animal's using its drinking water as an exogenous saliva to facilitate the swallowing of dry food (Vance, 1965; Kissileff, 1969b). The present study supports this view in that the great majority of drinking bouts follow immediately the taking of dry food into the mouth.

Desalivate mice on dry food show an increased rejection threshold to SOA. These results are similar to those reported by Vance (1965)

Table I. Comparison of SOA rejection levels in normal and desalivate F_1 mice.

	Experimental condition	N	Mean fluid and mash consumption	Mean rejection level	t	p
Preoperative (solutions)	Control	7	6.26 ml	1.46×10^{-5}M	0.426	.69
	Desalivate	9	5.91 ml	1.67×10^{-6}M		
Postoperative (solutions)	Control	7	5.49 ml	5.60×10^{-6}M	2.27	.04
	Desalivate	9	10.80 ml	5.50×10^{-5}M		
Postoperative (wet mash)	Control	6	11.34 g	1.15×10^{-4}M	0.390	.71
	Desalivate	8	10.91 g	9.76×10^{-5}M		

Table II. Results of 30-minute tests for prandial drinking on F_1 mice before (Test-1) and after (Test-2) desalivation.

Experimental condition	N	Total feeding bouts	Total drinking bouts	Mean duration of individual bouts (in seconds)		Number of drinking bouts preceded by feeding within		
				Feeding	Drinking	5 sec.	10 sec.	30 sec.
Control (Test-1)	7	53	57	42.8	12.7	0/57	1/57	2/57
Control (Test-2)	7	34	56	31.6	8.7	0/56	2/56	7/56
Desalivate (Test-1)	8	66	77	43.3	16.9	0/77	2/77	10/77
Desalivate (Test-2)	8	275	285	14.8	3.6	199/285	208/285	236/285

with rats tested on quinine hydrochloride. Whereas Vance suggests that a salivary influence on taste receptors is responsible for the alteration in threshold, the present study leads the author to postulate a "masking effect" as the basis of the elevated thresholds. The masking is a result of the modification in drinking behavior which occurs as a consequence of desalivation.

The masking hypothesis derives further support from a consideration of the magnitude of the differences in threshold between desalivate and normal animals. In the present study, the analysis of drinking in desalivate mice indicated that about 25% of their drinking bouts were **not** immediately preceded by feeding (Table II). This would allow the desalivate animal to encounter the test substance without the masking effect being operative. If it is the masking that occurs in the other 75% of the drinking bouts which causes the difference in threshold between normal and desalivate mice, then the masking hypothesis would predict an even greater difference in treshold if the desalivate mouse were completely prandial in its drinking. Kissileff (1969a) has reported in his analysis of feeding and drinking in desalivate rats that virtually 100% of their drinking follows within seconds the taking in of a morsel of dry food. Whereas the study shows that the rejection thresholds between normal and desalivate mice on SOA differ by a factor of 10. Vance's data with desalivate rats on QHCl show a difference in threshold of approximately 80 times between his control and desalivate animals. In the light of the threshold data on SOA mash reported above, this difference in magnitude is most likely due to the more complete masking that would occur in prandially drinking rats.

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A Summary of the Status of Harvest Mice, Cricetidae: *Reithrodontomys*, in Arkansas

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ABSTRACT

Although four species of harvest mice, *Reithrodontomys*, are known to occur in Arkansas, the distributional status of the genus in the state is poorly understood. Recent museum specimens significantly extend the range of *R. megalotis* and *R. fulvescens* in the state. *R. megalotis* is shown to range south through Phillips Co. in eastern Arkansas, and *R. fulvescens* is shown to range throughout most of the state, now including most of the Mississippi Alluvial Plain. A new specimen of *R. humulis* from Delaware Co., Oklahoma, suggests that this species probably ranges throughout northwestern Arkansas. *R. montanus* remains known only from Washington Co. in northwestern Arkansas.

INTRODUCTION

Four species of harvest mice, *Reithrodontomys*, are now known to occur in Arkansas. However, the distributional status of these rodents is unclear for the state. Sealander (1956) reported three species from Arkansas. The fulvous harvest mouse, *R. fulvescens* (J. A. Allen), was reported to be widely distributed throughout the state, although no records existed east of White County. Hall and Kelson (1959) and Schwartz and Schwartz (1959) considered northeastern Arkansas to be beyond the range of this species. *R. megalotis* (Baird) was known only from extreme northeastern Arkansas (south only to Craighead Co.). At this time, *R. humulis* (Audubon and Bachman) was known only from Sebastian Co. in western Arkansas. Recently, Sealander (1977) reported a specimen of *R. humulis* from Mississippi Co. in northeastern Arkansas, and Sealander and Gipson (1974) recorded *R. montanus* (Baird) from northwestern Arkansas. Recent museum specimens in the Collection of Recent Mammals at Arkansas State University (200 specimens of *Reithrodontomys*), the Vertebrate Collections at the University of Arkansas at Little Rock (26 specimens), and the Collection of Mammals at the University of Arkansas at Monticello (14 specimens) further clarify the Arkansas ranges of three of these species (*R. humulis, R. megalotis*, and *R. fulvescens*).

DISCUSSION

Sealander and Gipson (1974) reported three specimens of *R. montanus* from Arkansas. All were collected in Washington Co. in extreme western Arkansas. No additional specimens are known to us, and it appears that eastward colonization by the Plains Harvest Mouse has not extended beyond the western most tier of counties in northern Arkansas (Fig. 1).

Only two specimens of the Eastern Harvest Mouse, *R. humulis*, have been reported from Arkansas (Sealander, 1956, 1977). These specimens are from opposite sides of the state (Fig. 2), and indicate a need for an intensive search for additional specimens. Although we have no additional specimens of this rodent from Arkansas, we have a specimen of *R. humulis* collected in Delaware Co., Oklahoma, only a few kms west of Benton Co., Arkansas, and well north of the specimen from Sebastian County. Although Sealander (1977) reported a specimen from Mississippi County, several thousand trap-nights by us have netted over one hundred *R. megalotis*, but no additional specimens of *R. humulis* from northeastern Arkansas. It appears then, that a viable population of the Eastern Harvest Mouse exists in northwestern Arkansas, probably referrable to *R. h. merriami* as is our Oklahoma specimen. Additional data are needed to determine if this population is isolated, or contiguous with populations of *R. h. humulis* east of Arkansas.

Sealander (1975) reported the Western Harvest Mouse, *R. megalotis*, from the northeastern corner of Arkansas, and indicated specimens only from Clay, Craighead, and Mississippi Counties. We have collected 120 additional specimens, significantly extending the range of this species in Arkansas. Our specimens, and an additional specimen from Phillips Co., collected by Dr. Gary Heidt at UALR, reveal a continuous population of this rodent throughout northeastern and east-central Arkansas (Fig. 3). Further, our records indicate that the most dense populations of this mouse occur along railroad rights-of-way. It is probable then, that these sites represent primary avenues of dispersal for this species in Arkansas, although several of our specimens were collected from other shrubby or grassy habitats. Interestingly, *R. fulvescens* has several times been collected side by side with *R. megalotis* in extreme northeastern Arkansas. Evidence is not available concerning possible competitive interaction between these two harvest mice. Our data strongly suggest that *R. megalotis* is expanding its range southward in Arkansas, primarily along railroad routes.

In 1956, Sealander reported specimens of the Fulvous Harvest Mouse, *R. fulvescens*, from locations in 18 counties. He concluded that the species was "undoubtedly ... state wide in distribution although it [had] not been recorded from the eastern one-fourth of the State." Hall and Kelson (1959) and Schwartz and Schwartz (1959) excluded eastern Arkansas from its range, and Sealander (1975) reported *R. fulvescens*, absent from most of the Mississippi Alluvial Plain. We have accumulated 90 specimens from 17 additional counties (Fig. 4). Again, these specimens expand the known range of this species in Arkansas. These specimens reveal that *R. fulvescens* ranges throughout the Mississippi Alluvial Plain, with the possible exception of the northeastern section (east of Crowley's Ridge). We have found it to be abundant and co-existant with *R. megalotis* along Crowley's Ridge in northeastern Arkansas, which, together with previous records, suggests that the range of *R. fulvescens* is statewide in Arkansas.

SUMMARY

The range of *R. megalotis* in Arkansas is significantly greater than previously indicated. *R. megalotis* is abundant, and it is apparently expanding its range southward from northeastern and eastcentral Arkansas. *R. fulvescens* appears to range throughout most of Arkansas, including most of the Mississippi Alluvial Plain. *R. humulis* ranges over extreme northwestern Arkansas, and may extend eastward across the northern section of the state. *R. montanus* is presently known only from Washington Co., but probably occurs throughout northwestern Arkansas.

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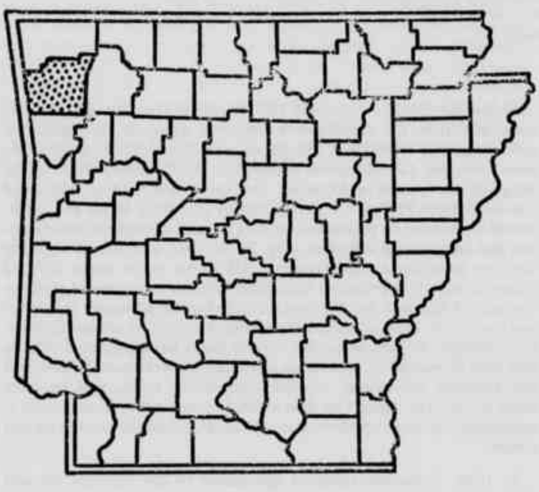

Figure 1. Counties from which specimens of *R. montanus* are known.

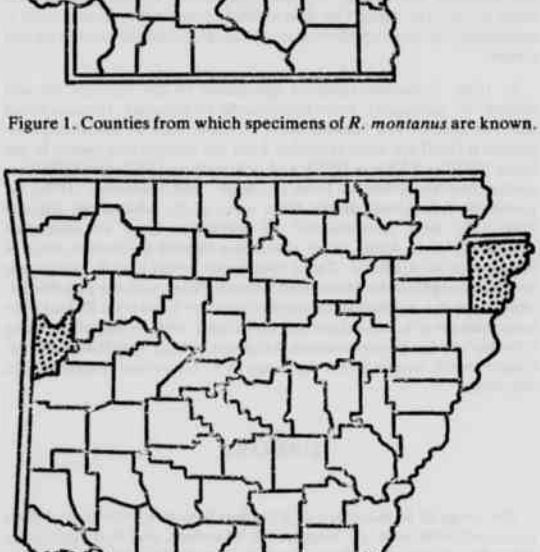

Figure 2. Counties from which specimens of *R. humulis* are known.

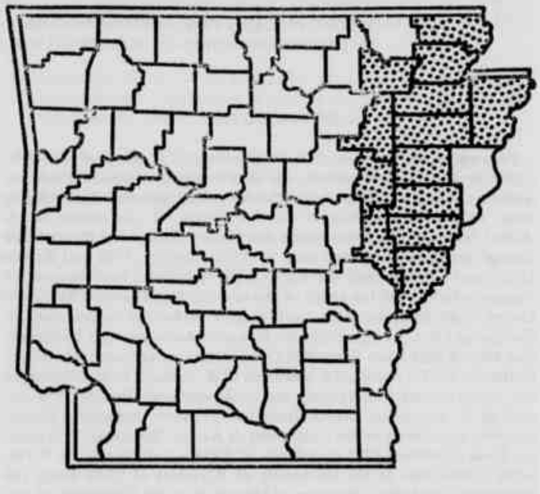

Figure 3. Counties from which specimens of *R. megalotis* are known.

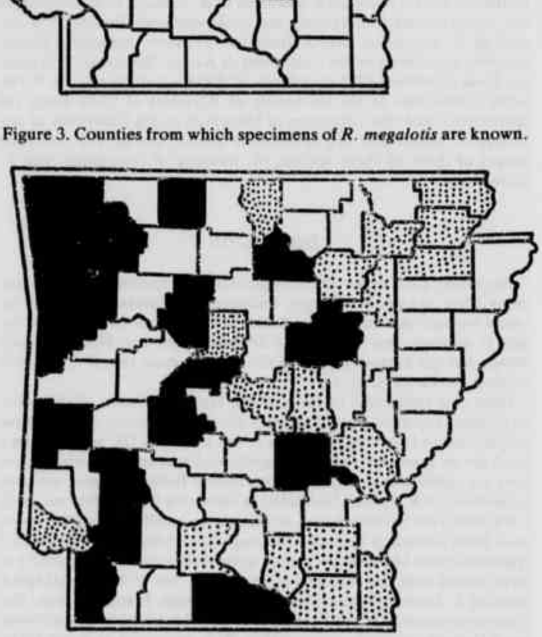

Figure 4. Counties from which specimens of *R. fulvescens* are known. Shaded counties are from Sealander (1956); stipled counties are new records.

Loss of Larval Fish by Epilimnial Discharge From DeGray Lake, Arkansas

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ABSTRACT

Weekly samples of larval fish were collected from water discharged from the epilimnion of DeGray Lake into the tailwaters, for power generation, from April through August, 1976 and 1977. Peak rates of loss measured were 1.4 larvae/m³ in May, 1976 and 2.7/m³ in April, 1977. Sunfish, shad and crappie made up 97% of an estimated 83.3 million fish lost in 1976, and 98% of 122.4 million lost in 1977. The most critical period for larval fish loss extended from the last week of April to the first week of June. No definite relationships were noted between length of the power generation period or power generation rate, and rate of larval fish discharge. Diel collections showed the rate of larval fish discharge to be lower and more uniform during darkness than during daylight.

INTRODUCTION

In the design and construction of many multi-purpose reservoirs, selective regulation of the depth of water discharge makes it possible to control the temperature of water released. The multi-outlet design at DeGray Dam allows for epilimnial, intermediate, or hypolimnial discharge. A concentrated study of the ecosystems of DeGray Lake and its tailwaters is being undertaken by the U. S. Fish and Wildlife Service and the U. S. Corps of Engineers, in cooperation with state and private universities, to determine the effects of multi-outlet water release. Little information is available on larval fish losses resulting from releases through any type of discharge design (Walburg, 1971; Snyder, 1975). As part of the research on the problem, larval fish loss has been monitored at DeGray Lake in an attempt to determine the species and numbers of larval fish entrained during power generation and the seasonal and daily periods of greatest vulnerability.

The present study concerns larval fish loss during epilimnial release; in later studies we hope to monitor loss during hypolimnial release. Eventually, an attempt will be made to assess the impact of larval fish loss on the reservoir fish population.

DESCRIPTION AND OPERATIONS OF THE RESERVOIRS

The multi-purpose DeGray Reservoir was created by a dam built on the Caddo River in 1969. At normal pool elevation (124.4 m, mean sea level - msl), it has an area of 5,427 ha with maximum and minimum depths of 57 m and 15 m, respectively. The multi-outlet intake structure allows water to be selectively withdrawn from one of three 6.4 m² openings, the midpoints of which are at elevations of 120.4, 115.8 and 108.2 m - msl (Middleton, 1967). All water releases have been made from the upper (epilimnial) outlet since impoundment.

Discharge depends on "peaking" power demands and maintenance of established water levels necessary for flood control. During the present study (April - September, 1975, 1976 and 1977), daily periods of discharge varied from a few minutes to 24 hours. Most power generating periods lasted less than 5 hours. Discharge rates ranged from 35 m³/s (1200 cfs) to 155 m³/s (5500 cfs). At maximum discharge rates, water current velocities 20 m in front of the intake tower did not exceed 0.15 m/s; at the sampling site below the dam, current velocity was 1.2 m/s.

Because the bottom of the upper outlet coincided with the top of the thermocline at normal water levels, we assumed that the water discharged involved mostly epilimnial water and only a small portion of the metalimnion. Similar situations have been noted in other reservoirs (Wunderlich and Elder, 1967; Wunderlich, 1971). Temperatures of the discharged water were similar to those of water in the epilimnion, supporting the assumption of epilimnial discharge.

METHODS

Fish larvae were collected at a point 40 m downstream from the discharge openings by a 3 m long, one meter townet of 0.79 mm (1/32 in) mesh size. The net was equipped with a flow meter and a collecting bucket. Samples were taken near the middle of the water column ranging from 1.0 to 1.5 m from the surface. A 2 h discharge on a predetermined schedule of power generation rate and time on each sampling date was arranged through the U. S. Army Corps of Engineers and the Arkansas Power and Light Company. After allowing a 20 minute flushing period to clear the sampling area, we fished the net each sampling day for 5-minute periods, separated by 15-minute intervals (six samples) in 1976, and for 10 minutes, separated by 20-minute intervals (four samples) in 1977. All routine sampling was conducted during daylight. In 1976, the sampling periods were alternated weekly between morning (0930 - 1130 h) and afternoon (1300 - 1500 h); in 1977, we sampled only in the afternoon (1300 - 1500 h). Discharge rates on sampling dates varied from 85 to 155 m³/s. It was estimated that the net filtered about 0.6% of the water being discharged during the fishing period, about 0.15% of the water discharged during the 2-hour sampling period, and as little as 0.003% of the water discharged during a typical week. Extra samples were taken during periods of long-term generation and during one 24-h period.

Larval fish were placed in 10% formalin solution and returned to the laboratory for determination of species, lengths, and weights and density (no./m³). Because identification of the larvae to species was uncertain, some were identified only to genus. Shad over 20 mm long were identified to species. The volume of water discharged each week was calculated from weekly summations of daily discharge furnished by the U. S. Army Corps of Engineers. The midpoint of each weekly summation included the weekly sampling date. The mean number of larvae per cubic meter of water strained on the sampling date, multiplied by the total volume of water discharged during the corresponding week, provided the estimated larval fish loss.

Preliminary sampling in 1975 (18 April to 5 September) indicated that vulnerability of larvae to discharge was highest from April through August. Therefore, estimates of larval fish loss were confined to these 5 months in 1976 and 1977.

RESULTS AND DISCUSSION

Fish larvae collected, in order of abundance, included sunfish, *Lepomis* sp.; shad, *Dorosoma*, sp; crappie, *Pomoxis* sp; logperch, *Percina caprodes;* brook silverside, *Labidesthes sicculus;* shiners, *Notropis* sp; darters, *Etheostoma* sp; channel catfish, *Ictalurus punctatus;* flathead catfish, *Pylodictis olivaris;* centrarchid bass, *Micropterus* sp.; and white bass, *Morone chrysops.* Most larvae collected were 5 to 30 mm long. Sunfish, shad, and crappie made up 97% of the estimated 83.3 million larval fish lost in 1976 and 98% of the estimated 122.4 million lost in 1977 (Table I). On the basis of limited sampling, the larval fish loss in 1975 was estimated at 171 million.

The seasonal occurrence of larval fish in the discharge appeared to closely follow the expected abundance of larval fish in the reservoir. Darters were the first to appear in the discharge in early April, followed by crappie about mid-April, depending on early spring water temperatures. Peak numbers of crappie occurred in the discharge during the first week in May, 1976 and in the last week in April, 1977. No crappie were caught after the last week in June of either year. A few shad were in the discharge in early April, most were collected in May, and progressively decreasing numbers were taken during June, July, and August. Sunfish first appeared in the samples in the second week in May, peaked during June, and maintained relatively high numbers through July and August, reflecting their extended spawning period (Fig. 1). The critical period of spawning, hatching, and vulnerability to discharge for most species occurred during the 6-week interval from the last week in April through the first week in June. During most years, high discharge volumes coincided with this period (42% in 1974, 62% in 1975, 35% in 1976, and 34% in 1977 of the April-August total).

On a monthly basis, maximum losses for all species combined occurred during May of both 1976 and 1977 (Fig. 2). Estimates of total larval fish losses were higher in 1977 than in 1976, even though the discharge volume was lower than in 1976 (Table I, Fig. 2). Among the three major genera, only *Dorosoma* showed greater losses in 1976 than in 1977. In 1977 shad populations in the lake were low because of the poor reproduction of threadfin shad *(Dorosoma petenense)*, brought about by winter mortality of adults (Multi-Outlet Reservoir Study, U. S. Fish and Wildlife Service, unpublished data).

In 1976 we attempted to determine the effects of power generation rate on larval fish loss. Once each month (June-August), samples were collected at both a low discharge rate (90 m^3/s) and a high discharge rate (155 m^3/s). One set of six samples was collected during 2 hours of power generation in the morning, and another set during 2 hours of power generation in the afternoon. Significant differences (.05 level) between mean numbers of fish larvae collected at high and low discharge rates were noted for June and July, but not for August. The June and August tests indicated that more larvae per cubic meter were discharged at the lower power generation rate. The relation between length of power generation, discharge rate, and larval fish loss was not clearly established.

The rate of water discharge appeared to influence the size of fish entrained. Only shad larvae discharged at high and low power generation rates were compared, because they made up most of the catch when the comparisons were made. On 23 June, the mean length of shad collected was 13.0 mm during the low generation rate and 15.6 mm during the high generation rate. On 21 July, the respective mean lengths were 17.9 and 19.9 mm. There were too few shad in the August samples to support a sound comparison. The night before the 21 July samples were taken, midwater trawl catches from the lower portion of the lake showed the mean length of shad larvae to be 22.5 mm, indicating that the larger shad larvae evaded entrainment at both power generation rates (Multi-Outlet Reservoir Study, unpublished data).

Differences were also noted between larval fish discharge rates on routine sampling dates and the rates during long-term generation periods that occurred 1 to 3 days before or following a routine (2 h) sample (Table II). The comparisons did not show a trend toward an increase in fish discharge rate with an increase in the length of generating time, as might be expected. We thought that lake currents established during long periods of power generation might influence the rate at which larvae were entrained; however, further studies are needed to define the reservoir current patterns established by different discharge rates and lengths of power generating periods. The rate of fish loss (no./m^3) did show an increase with an increase in water discharge rate, except for the 15-17 June, 1977 comparison.

It has been shown that the vertical distribution of larval shad varies between day and night (Netsch et al., 1971). In daytime, fish larvae were shown to aggregate in scattered schools, whereas at night the distribution was more uniform. This could account for some of the

Table I. Estimated loss by number (thousands) and percentage (in parentheses) of larval fish through the discharge from DeGray Lake, 1976-77.

Species	Year	
	1976	1977
Shad	53,396 (64.1)	37,846 (30.9)
Sunfish	19,389 (23.3)	55,412 (45.3)
Crappie	8,871 (10.7)	25,244 (20.6)
Logperch	1,198 (1.4)	3,532 (2.9)
Brook silverside	349 (0.4)	136 (0.1)
Other	61 (0.07)	262 (0.2)
Total	83,264	122,432

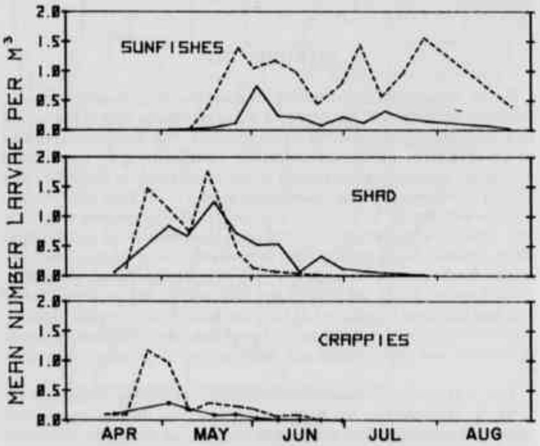

Figure 1. Seasonal variation in number of larval sunfish, shad, and crappie per cubic meter of water from DeGray Lake discharge 1976 (solid line) and 1977 (dashed line).

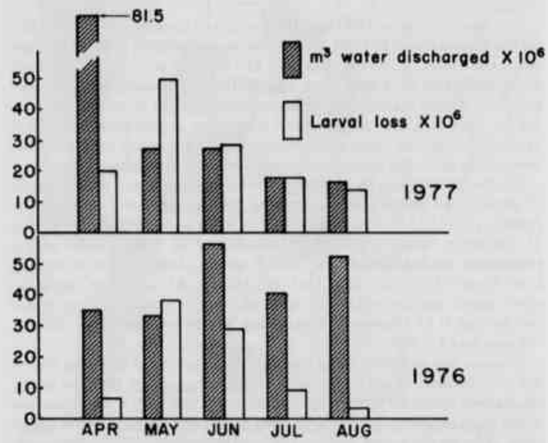

Figure 2. Monthly estimates of discharge volume and larval fish loss, DeGray Lake, 1976 and 1977.

variation in the numbers collected during daytime discharge. In a diel study to determine the relation between daytime and nighttime power generation and larval fish loss, we sampled during 2 hours of power generation every 6 hours from 1300 h on May 4 through 1500 h on May 5. The sampling interval followed the routine pattern. Rates of larval fish loss decreased during periods of twilight and darkness (Fig. 3). Ranges within the sampling periods indicated a more uniform rate of loss during periods of darkness, coinciding with the expected nighttime distribution of larval fish in the lake.

Our routine sampling was done during daylight because that was when most power generation occurred. We believe that the distribution of larval fish in the lower portion of the lake may have influenced the pattern of larval fish discharge to a greater degree than the power generation rate or the length of the power generating period. More intensive sampling is needed to evaluate the relation between power generation rate, length of the power generating period, and larval fish discharge.

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Table II. Comparisons of larval fish discharge rates during long-term power generation with those during routine sampling within similar time periods.

Date	Number of samples	Hours of discharge	Discharge rate (m^3/s)	Mean number/m^3
1976				
June				
21	4	7	99	0.163
23	6	2	125	0.420*
25	12	18	155	0.732
1977				
May				
9	4	12	99	0.164
10	3	15	113	0.445
11	4	2	122	0.953*
June				
15	4	2	120	1.137
17	4	21	114	1.143

*Significantly different (at .05 level) than long-term means for adjacent dates.

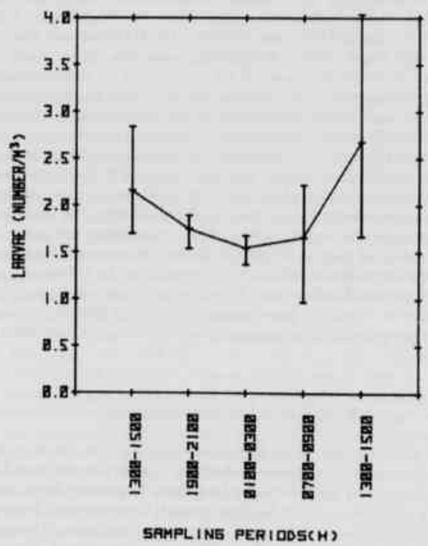

Figure 3. Rates of larval fish discharge (mean and range of four samples) during diel sampling May 4-5, 1977, DeGray Lake.

Distribution and Habitat of the Taillight Shiner, *Notropis maculatus* (Hay), in Arkansas

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ABSTRACT

The distribution of the taillight shiner, *Notropis maculatus* (Hay), within Arkansas is discussed based on personal collections, literature citations and a search of museum records. *N. maculatus* appears to be a typical Coastal Plain physiographic province inhabitant occurring below the Fall Line, and it nears its western and northern range limits west of the Mississippi River in Arkansas. Data are provided on preferred habitat, and suggestions are provided as to the current status of the taillight shiner within Arkansas.

INTRODUCTION

Cyprinid fishes of the genus *Notropis* are among the most numerous, yet least known species taxonomically and distributionally of the Arkansas ichthyofauna. One of these, the taillight shiner, *Notropis maculatus* (Hay), is a small, distinctive shiner which ranges from southeastern Kentucky to extreme southeastern Oklahoma, east along the Gulf Coast to Florida, and north to the Waccamaw drainage in North Carolina (Miller and Robison, 1973; Cowell and Barnett, 1974; Burr and Page, 1975). Within Arkansas this shiner nears the western and northern terminus of its range west of the Mississippi River and previously has been seldom encountered, due in part to its small size and inadequate collecting of the lowland, often inaccessible habitats preferred by this species. Such reported scarcity originally precipitated listing of *N. maculatus* as rare and vulnerable (rare) in Arkansas by Robison (1974) and Buchanan (1974), respectively. New collections from throughout the Coastal Plain are now available necessitating a redescription of the geographic range of *N. maculatus* within Arkansas and a re-evaluation of its status within the state. In a continuing series of papers dealing with the Arkansas ichthyofauna, this study details known localities for *N. maculatus* in Arkansas based on extensive personal collections, literature citations, and a search of museum records. Data are presented on preferred habitat, and suggestions are provided on the current status of *N. maculatus* within the state.

METHODS AND MATERIALS

Material used in this study is housed variously in the Southern Arkansas University Vertebrate collection, the Arkansas State University Museum, and the Northeast Louisiana University Museum of Zoology. In addition, several locality records were gleaned from the literature. Specific locality data are presented in the form of museum records by county in Arkansas. Localities are not repeated, although several collections may have been made at the same time or site. The appropriate museum catalog number is followed by the number of specimens (in parentheses), and brief locality data with survey coordinates are provided when available. The following institutional abbreviations are used in the text: SAU - Southern Arkansas University; ASU - Arkansas State University; and NLU - Northeast Louisiana University.

In order to gain insight into the habitat preferences of *N. maculatus*, certain physicochemical parameters were measured in accordance with standard methods (American Public Health Association, 1971) at selected sites in the Ouachita River basin where the species was collected. Additional habitat data were assembled from detailed field notes of ten collections of *N. maculatus* made by the writer.

DISTRIBUTION

In Arkansas, *N. maculatus* has been previously reported from several scattered localities throughout the Coastal Plain physiographic province. Initially, Black (1940) reported *N. maculatus* from Arkansas on the basis of two juvenile specimens taken during his state ichthyofaunal survey from the upper Saline River (Ouachita River system). Not until over thirty years later were additional specimens collected from Bayou Dorcheat (Red River system) in Columbia County, by the author, thus re-establishing its presence in Arkansas. Buchanan (1973) illustrated this locality along with another site in the St. Francis River drainage in eastern Arkansas. Since that time, an additional 23 collections from 16 different locations in Arkansas have been made by the author and others.

Typically, as in other areas of its range, these new collections suggest *N. maculatus* occupies low-gradient streams below the Fall Line in the Coastal Plain physiographic province of Arkansas (Figure 1). The Fall Line is an ecotonal belt of varying width (Thornbury, 1965) which describes an abrupt transition from the Coastal Plain physiographic region to the Interior Highlands. Previous collections, a recent survey of the Arkansas River (Buchanan, 1976), and several ongoing ichthyofaunal surveys of the tributary streams of the Arkansas River have failed to reveal the presence of the taillight shiner above the Fall Line.

N. maculatus nears its northern range limits west of the Mississippi River in northeastern Arkansas, as Pflieger (1975) noted only four localities in Missouri. These are in the state's extreme southeastern tip near the Arkansas-Missouri border. Within Arkansas the northernmost record for *N. maculatus* (ASU 2551) was collected near the Fall Line from an oxbow lake of the Black River in Randolph County. *N. maculatus* is apparently able to take advantage of the suitable backwater habitat conditions of the Black River northward along its margins as the river traverses the eastern edge of the Ozark Plateau, thus penetrating into the lowlands of southeastern Missouri.

An apparent hiatus which seems to exist between these northern Arkansas populations in Craighead, Jackson, and Randolph Counties (Figure 1) and more southerly ones is probably a reflection of the paucity of collecting along the lower White, L'Anguille, and St. Francis rivers and the associated lowland streams dissecting this region rather than an indication of true absence. *N. maculatus* is quite common in the extreme southeastern portion of the state in many of the oxbows along the Mississippi River, especially those east of the levee near the river proper. Many of the weed-choked borrow pits along and seasonally contiguous with the river are inhabited by the taillight shiner. The taillight shiner appears to become more abundant in the southern portion of the state, particularly in the Ouachita River system where the largest collections appear; however, this may simply reflect a more intensive collecting effort in this precise area. Two of the largest series known from Arkansas (NLU 31553 of 129 specimens and NLU 31679 of 211 specimens) were both taken from backwater areas along the Ouachita River. The largest series (NLU 32152 of 239 specimens) was collected from Bayou Bartholomew in Jefferson County.

Westward *N. maculatus* becomes less common, although it probably inhabits some of the numerous oxbows of the Red River and Little River systems which have not yet been adequately sampled. Suitable habitat abounds along these systems. However, although several ichthyofaunal surveys have been conducted in the Arkansas portion of the Little River system, no taillight shiners have been captured (Ethridge, 1974; Cloutman and Olmsted, 1974; Douglas, per comm.; pers. collections).

Listed below are the localities from which records have been assembled. Localities are listed only once, even though more than one collection may have been taken from that particular site.

ARKANSAS CO.: Bayou Meto (Buchanan, 1974). **ASHLEY CO.:** NLU 31553 (129). Backwaters of Ouachita River at U. S. Hwy. 82. **BRADLEY CO.:** NLU 31679 (211). Backwaters of Ouachita River in Moro Bay State Park. **CALHOUN CO.:** SAU uncat. (8). Backwater of Ouachita River along U. S. Hwy. 167, 12 mi. S.W. of Hampton (Sec. 2, T16S, R14W). SAU uncat. (1). Locust Bayou, 3.5 mi. S. of Locust Bayou, Ark. **CHICOT CO.:** SAU uncat. (15). Barrow pit under U. S. 82 bridge over Mississippi River. SAU uncat. (21). Borrow pit 8 mi. S. of U. S. Hwy. 82 bridge. **COLUMBIA CO.:** SAU uncat. (1). Big Creek at St. Hwy. 132, 1 mi. W. of Magnolia. SAU uncat. (12). Bayou Dorcheat at St. Hwy. 160 bridge (Sec. 9, T19S, R22W). **CRAIGHEAD CO.:** ASU 2993 (1). St. Francis River, 1.4 mi. N. of Lake City. ASU 4880 (13). Oxbow of St. Francis River (Sec. 14, T14N, R63). **GRANT CO.:** Saline River (Black, 1940). **JACKSON CO.:** ASU 2745 (18). Village Creek, 1 mi. S. of Alicia (Sec. 4 and 9, T14N, R1W). ASU 2908 (5). Village Creek, 3.5 mi. E. Tuckerman (Sec. 26, T12N, R2W). **JEFFERSON CO.:** NLU 32052 (239). Bayou Bartholomew (Sec. 28, T6S, R9W). **MONROE CO.:** Tributary to Water's Bayou near Hog Thief Lake, White River National Wildlife Refuge (Buchanan, 1974). **RANDOLPH CO.:** ASU 2551 (20). Oxbow of Black River, Gas Plant lake (Sec. 35, T20N, R2E). **ST. FRANCIS CO.:** Keithley Lake (Buchanan, 1974). **UNION CO.:** NLU 31432 (24). Backwaters of Ouachita River, ½ mi. E. of U. S. Hwy. 167 on road to Calion. SAU uncat. (5). Grand Marais Lake near Huttig.

HABITAT

Pflieger (1971) reported *N. maculatus* from sluggish sections of lowland rivers and creeks in Missouri. Miller and Robison (1973) described similar preferred habitat in Oklahoma. Douglas (1974) collected most specimens in Louisiana in quiet bayous, oxbows and large lakes and less often in rivers and streams. In Arkansas, the taillight shiner seems to show a proclivity for shallow, tannin-stained waters of low-gradient streams, sloughs, lakes, including oxbows, and swamps of the Coastal Plain physiographic province, particularly those less disturbed portions. Localities in lotic situations where *N. maculatus* is taken are typically backwater areas, without direct current, over substrates of decomposing vegetation, silt and soft mud. Gravel areas are generally avoided as are swifter stream sections. In lentic waters *N. maculatus* typically frequents weed-choked lake margins, but also can be found distributed in deeper waters. *N. maculatus* seems to prefer waters with medium to heavy aquatic vegetation, including *Myriophyllum*, *Lemna*, *Typha latifolia* L., *Nuphar* sp., and *Taxodium distichum* (L.) Rich. Field and laboratory observations suggest *N. maculatus* is a schooling, mid-water shiner which utilizes the luxuriant aquatic vegetation normally present for cover. Many of the lowland streams where *N. maculatus* occurs have a moderate to heavy canopy of bottomland hardwoods; however, the species frequents areas in the middle of oxbow lakes such as Grand Marais, Union County, away from any cover, where water temperatures are relatively higher than in marginal areas.

Streams in the Ouachita River basin, where *N. maculatus* was studied in more detail, were characterized by the following physicochemical parameters: pH ranged from 6.1 to 6.9; dissolved oxygen from 5.3 to 7.0 mg/1; total solids of 105 to 162 mg/1; and dissolved solids of 97 to 141 mg/1. The highest recorded water temperature associated with this species was 26°C. Turbidity ranged from less than 25 to 130 Jackson turbidimeter units. While these data are not intended to be indicative of parameter limits for *N. maculatus*, they are suggestive of the general type of waters frequented.

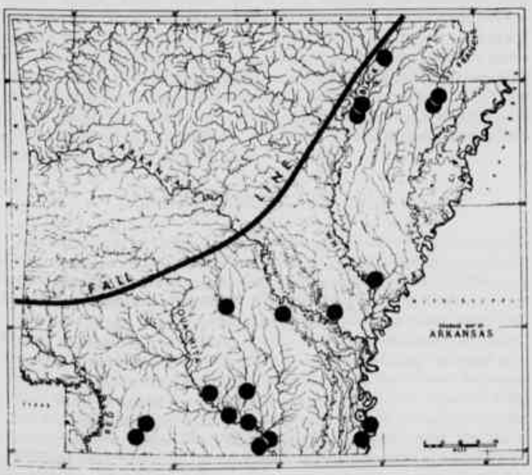

Figure 1. Distribution of *Notropis maculatus* in Arkansas.

STATUS

Unfortunately, there is little baseline data to clearly illustrate the decline of the taillight shiner in the ecologically disturbed areas of the Coastal Plain physiographic province, especially of the eastern sector of Arkansas. Early workers neglected these inhospitable lowland regions of the state in favor of the clear, swift streams of the Ozark uplands. Because of the scarcity of documented collections and known destruction of habitat in eastern Arkansas both Robison (1974) and Buchanan (1974) chose to list *N. maculatus* as a rare state inhabitant until further work could be done to more clearly establish the status of this shiner. With additional intensive collecting over the past few years throughout the Coastal Plain, the status of *N. maculatus* can presently be refined more accurately.

N. maculatus has probably inhabited the lower Mississippi Valley since preglacial time (Pflieger, 1971) and thus probably the Coastal Plain province of Arkansas. There is little doubt that *N. maculatus* has declined in abundance in the once sluggish, meandering streams of eastern Arkansas. Channelization, clearing of prime timberland and the widespread application of pesticides to row crops in historic times have drastically altered the ecological balance of that region of the state (Holder, 1970) thereby destroying or otherwise altering streams which probably were formerly inhabited by *N. maculatus*.

Nevertheless, despite its probable extinction from some areas of its former range in eastern Arkansas, *N. maculatus* seems to be surviving adequately in sloughs, oxbow lakes, margins of various large rivers and in sluggish streams of the less ecologically disturbed south-central and southwestern portions of the state, particularly in the Ouachita River system. Because of the number of recent collections in Arkansas indicating a rather widespread, if spotty, occurrence within the state, a status of "uncommon" is urged for *N. maculatus*.

ACKNOWLEDGEMENTS

My sincere appreciation is extended to Dr. Neil H. Douglas, Northeast Louisiana University, who kindly allowed the author to utilize museum records in his care and to Dr. George L. Harp, Arkansas State University, who supplied records from the ASU museum collection.

Special thanks go to the many SAU students who so enthusiastically participated in the field work, especially Steve Pelt and Steve Winters.

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The Fishes of Moro Creek, A Lower Ouachita River Tributary, in Southern Arkansas

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ABSTRACT

The fishes of Moro Creek, a fifth order stream tributary of the lower Ouachita River in southern Arkansas, were sampled from 1972-1977. Field collections, literature records and museum records revealed a total of 63 species representing 14 families. An undescribed cyprinid, the bluehead shiner, is reported from Moro Creek for the first time. In general, longitudinal zonation of fish species was apparent as species diversity increased downstream. Stream inhabitants were typical Coastal Plain fishes of the lower Ouachita River system.

INTRODUCTION

Distributional data on fishes inhabiting the Coastal Plain physiographic province of Arkansas have not accumulated as rapidly as have data on Interior Highland fishes due in part to the lack of a concentrated collecting effort in this lowland region. In particular, the lower Ouachita River system has been generally neglected by ichthyologists (Robison, 1975). Except for a survey of the fishes of the main Ouachita River by Raymond (1975), Reynolds' (1971) study on the fishes of the Saline River (a major eastern tributary of the Ouachita River) and distributional records added by Robison (1975) from the lower portion of the system, little in the way of systematic documentation of the fish fauna of this region has been accomplished. Smaller tributaries of the Ouachita River have received even less attention, being largely ignored by previous workers.

Because of the paucity of even baseline data for many areas of the Coastal Plain portion of the Ouachita River, an investigation was undertaken to survey the fishes of Moro Creek, also known as Moro Bayou, a lower Ouachita River tributary in southern Arkansas. Data of this kind are becoming increasingly important with the mining of lignite coal a distinct possibility in the near future in the lower Ouachita River basin.

Historically, collections of fishes from Moro Creek have been meager due in part to the creek's rather small size and lowland sluggish nature. Black (1940) visited the stream initially and collected only four species. Later, Buchanan (1973) illustrated a single collection locality from Moro Creek for the period 1960-1972 based on Arkansas Game and Fish Commission stocking and rotenone records; however, he listed 23 species in addition to those of Black (1940) bringing the total number of fish species reported from Moro Creek to 27 prior to this study. Our collections from Moro Creek began in 1972 and have continued to the present. A total of 32 collections from Moro Creek were made during the period 1972-1977.

DESCRIPTION OF THE AREA

Moro Creek is an Order 5 tributary stream (as ascertained from the county maps published by the Arkansas Highway Department) of the lower Ouachita River in southern Arkansas approximately 70 miles in length and drains approximately 550 square miles. The stream is contained within the West Gulf Coastal Plain physiographic province. Arising in northeastern Dallas County near the community of Tulip, Arkansas, Moro Creek flows southeast through rolling forested terrain into northeastern Cleveland County to form the border between Dallas and Cleveland Counties and further south, to separate Calhoun and Bradley Counties, before emptying into an oxbow of the Ouachita River, Moro Bay, which in turn connects with the main river channel (Figure 1). Moro Creek drains Forested Coastal Plain Quaternary Alluvium and terrace deposits with some tributaries heading in Tertiary Claiborne deposits. Soils are primarily of the Caddo, Saffell-Ruston and Caddo-Weston-Cahaba series. At its mouth, Moro Creek enters the Bottomland and Terrace deposits consisting of deep alluvial soils formed by sediments from the Ancestral Ouachita River (Arkansas Soil and Water Conservation Commission, 1970).

In its upper reaches, Moro Creek is characterized by small, shallow pool regions with occasional poorly defined gravel riffles while in its lower course the stream takes on a more sluggish nature as the gradient lessens. During low water levels the upper portions of Moro Creek above Fordyce (Dallas County) occasionally become intermittent. Tributaries of this system are small and include Bryant, Hurricane, Caney, Whitewater, Jack's and Lloyd Creeks.

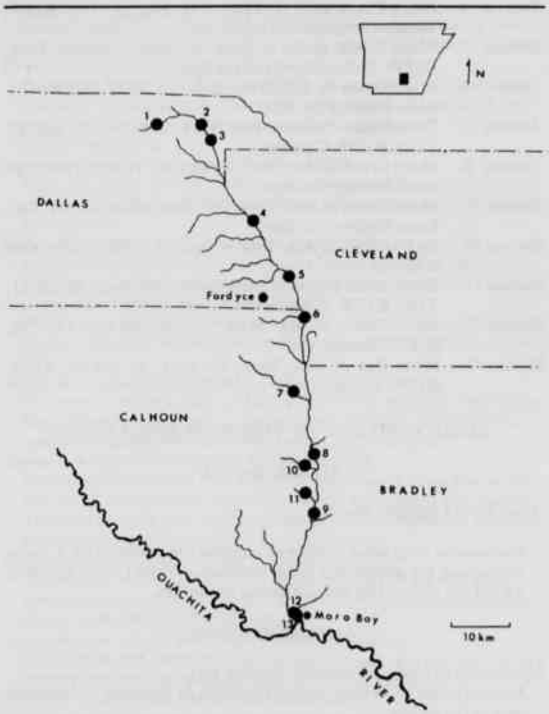

Figure 1. Moro Creek Drainage.

Within the basin, January air temperatures range from 15°-18°C while July air temperatures range from 27°-28°C. An oak-gum-cypress association predominates within the Moro Creek basin; however, loblolly and shortleaf pines are abundant throughout. Moro Creek receives pollution from a creosote plant and plywood manufacturer near Fordyce, Arkansas (Arkansas Dept. of Pollution Control and Ecology, 1976a; 1976b).

METHODS

The majority of collections were taken with 10-ft. and 15-ft. seines with 1/8 inch meshes. In the lower, larger stream reaches, a 20-ft., 1/8 in. mesh seine was used, and a six-ft. seine with 1/8 in. mesh was also used extensively in areas especially difficult to collect. Specimens were preserved in 10% formalin in the field before being placed in 40% isopropyl alcohol for permanent storage. Most of the specimens have been retained in the Southern Arkansas University Vertebrae Collection; however, gifts of some species have been made to other institutions.

Scientific and common names of fishes follow those of Bailey, et. al. (1970) except where noted.

Thirteen stations were established based on their accessibility, location in the basin, and diversity of habitats to produce desired maximum species diversity in collections. The following is a brief description of each station.

Moro Creek Stations

Station 1. Moro Creek, 1½ mi. N. of Ark. Hwy. 48. Sec. 27, T7S, R15W. Dallas Co.

Station 2. Moro Creek at TAR 3½ mi. E. of Carthage, Sec. 2, T8S, R14W. Dallas Co.

Station 3. Moro Creek at Ark. Hwy. 48. Sec. 27, T7S, R14W. Dallas Co.

Station 4. Moro Creek at U. S. Hwy. 167. Sec. 15, T9S, R13W. Dallas-Cleveland Co. line.

Station 5. Moro Creek at U. S. Hwy. 79. Secs. 7 and 8, T10S, R12W. Dallas-Cleveland Co. line.

Station 6. Moro Creek at Ark. Hwy. 8. Sec. 4, T11S, R12W. Calhoun-Bradley Co. line.

Station 7. Whitewater Creek at Ark. Hwy. 274. Sec. 21 and 22, T12S, R12W. Calhoun Co.

Station 8. Moro Creek at Ark. Hwy. 4. Sec. 34, T13S, R12W. Calhoun-Bradley Co. line.

Station 9. Moro Creek at Ark. Hwy. 160. Sec. 9, T5S, R13W. Calhoun-Bradley Co. line.

Station 10. Jack's Creek at Ark. Hwy. 4. Sec. 34, T13S, R12W. Calhoun Co.

Station 11. Jolly Creek, 2.5 mi. S. of Summerville, Secs. 20 and 21, T14S, R12W. Calhoun Co.

Station 12. Moro Creek at Ark. Hwy. 15 Secs. 20 and 21, T7S, R14W. Bradley Co.

Station 13. Moro Bay at Ark. Hwy. 15. Secs. 20 and 21, T16S, R12W. Bradley Co.

ANNOTATED LIST OF FISHES OF MORO CREEK

Amiidae (Bowfins)

Amia calva Linnaeus. Bowfin.

Discussions with local fishermen confirm the presence of *A. calva* throughout the middle and lower portions of Moro Creek; however, we did not collect this species during the survey.

Lepisosteidae (Gars)

Lepisosteus oculatus (Winchell). Spotted gar.
An inhabitant of heavily vegetated pools, *L. oculatus* was uncommon in the system.

Lepisosteus osseus (Linnaeus). Longnose gar.
Rare inhabitant of the lower stream sections and backwaters of Moro Bay.

Esocidae (Pikes)

Esox americanus vermiculatus Lesueur. Grass pickerel.
Quite abundant and widespread throughout the system in weedy sluggish pool habitats. Probably the major predator in the Moro Creek ecosystem.

Esox niger Lesuer. Chain pickerel.
Although not as common as *E. a. vermiculatus*, the chain pickerel was taken primarily in the lower sections of the creek near the mouth, but not syntopically with the grass pickerel.

Clupeidae (Herrings)

Dorosoma cepedianum (Lesueur). Gizzard shad.
Only two speciemsn of this species were taken. As the gizzard shad prefers more lacustrine type habitats generally unavailable in Moro Creek, *D. cepedianum* appears to be rare in the system and may enter only occasionally from the Ouachita River.

Dorosoma petenense (Gunther). Threadfin shad.
Buchanan (1973:Map 20) reported a single record of D. petenense from Moro Creek; however, we did not collect it in this survey.

Catostomidae (Suckers)

Erimyzon oblongus (Mitchill). Creek chubsucker.
Most common sucker in the higher gradient upper stream sections generally avoiding the sluggish lower regions.

Erimyzon sucetta (Lacepede). Lake chubsucker.
The lake chubsucker seems to replace *E. oblongus* in the lower portion of the system as Moro Creek becomes more sluggish and vegetated backwaters predominate near the mouth. Young-of-the-year individuals were collected at Ark. Hwy. 160 on 5 May 1975.

Ictiobus cyprinellus (Valenciennes). Bigmouth buffalo.
Although not collected in our survey, Buchanan (1973) indicated one record of this species. *I. cyprinellus* normally inhabits more lacustrine or large river habitats than are present in Moro Creek.

Minytrema melanops (Rafinesque). Spotted sucker.
While widespread in Moro Creek, *M. melanops* was not found to be abundant, except in the large deep pool at Station 9.

Moxostoma poecilurum (Jordan). Blacktail redhorse.
A single adult male specimen was found dead at Station 9.

Cyprinidae (Minnows and Carps)

Campostoma anomalum pullum Agassiz. Central stoneroller.
Uncommon stream resident. Generally prefers higher gradient streams.

Ctenopharyngodon idellus Cuvier and Valenciennes. Grass carp.
This controversial introduced Asian species was recorded by Buchanan (1973) from Arkansas Game and Fish Commission records; however, we did not collect it.

Hybognathus hayi Jordan. Cypress minnow.
The cypress minnow preferred the lower stream sections where it was quite common in sluggish pools over mud substrates with vegetation.

Notemigonus crysoleucas (Mitchill). Golden shiner.
This ubiquitous shiner was collected throughout the system.

Notropis atherinoides Rafinesque. Emerald shiner.
The emerald shiner is rare in Moro Creek, being contained in the lower sections where this population has free access to the larger Ouachita main channel in which it is common. Generally prefers large riverine situations.

Notropis buchanani Meek. Ghost shiner.
A single specimen was taken during our survey. Probably a waif from the Ouachita River.

Notropis cornutus isolepis Hubbs and Ortenburger. Southern common shiner.
We follow Miller (1968) in considering *N. cornutus isolepis* a subspecies of *N. cornutus* rather than of *N. chrysocephalus*. Although widely distributed in the system, the southern common shiner

never was taken in large numbers in Moro Creek. Generally confined to upper areas over gravel and sand substrates above and below riffles and in pools where moderate current flows.

Notropis emiliae (Hay). Pugnose minnow.
Common. The pugnose minnow was collected in the lower stream reaches where it frequented vegetated pools and backwater areas away from the main current.

Notropis fumeus Evermann. Ribbon shiner.
Taken occasionally syntopically with *N. umbratilis*, the ribbon shiner was collected in moderate numbers in sluggish pools over mud and sand substrates in the lower reaches.

Notropis sp. Bluehead shiner.
The bluehead shiner is presently being described by Reeve M. Bailey and the senior author. Specimens were taken in pool and backwater areas and were normally associated with aquatic vegetation.

Notropis maculatus (Hay). Taillight shiner.
The taillight shiner was collected only from one locality in a three foot backwater pool over sand with heavy growths of filamentous algae. Rare in the system except possibly in Moro Bay where it may be common.

Notropis texanus (Girard). Weed shiner.
A typically lowland stream fish, the weed shiner was taken sporadically in the system in the lower stream sections where a noticeable current prevailed over a rather sandy or mud/sand substrate without vegetation.

Notropis umbratilis (Girard). Redfin shiner.
The redfin shiner was the most abundant and widespread species in the Moro Creek system having been taken at every station sampled. The extremely variable habitat requirements of this species facilitates its use of the entire stream length of Moro Creek.

Notropis venustus (Girard). Blacktail shiner.
Rarely taken except in the lowest portion of the creek near the confluence with the Ouachita River at Moro Bay. Another of the common species of the Ouachita River which seldom enters Moro Creek.

Pimephales notatus (Rafinesque). Bluntnose minnow.
Collected only sparingly in the upper and middle stream sections.

Ictaluridae (Freshwater Catfishes)

Ictalurus melas (Rafinesque). Black bullhead.
Common ictalurid in the lower stream sections over sand and mud bottoms.

Ictalurus natalis (Lesueur). Yellow bullhead.
The yellow bullhead was uncommon in Moro Creek and seemed to prefer brush piles and vegetation in the upper stream reaches avoiding the more sluggish lower sections.

Ictalurus nebulosus (Lesueur). Brown bullhead.
Buchanan (1973:Map 110) reported a single collection of *I. nebulosus* introduced into Moro Creek by the Game and Fish Commission. This species was not collected in our survey.

Noturus gyrinus (Mitchill). Tadpole madtom.
Rare. Only two specimens of *N. gyrinus* taken in the survey. Both collected in rubble over sand substrates.

Noturus nocturnus Jordan and Gilbert. Freckled madtom.
While no ictalurid was collected in large numbers in Moro Creek, the freckled madtom was the most abundant and common ictalurid taken during the survey. Although Taylor (1969) reported this species was seldom found in streams with shifting sand bottoms, such does not seem to be the case in Moro Creek, as specimens were frequently taken over sandy areas in water eight inches to two feet deep. This observation in Moro Creek holds true for most Ouachita River tributaries which support good *N. nocturnus* populations (HWR, pers. observation).

Cyprinodontidae (Killifishes)

Fundulus notti (Agassiz). Starhead topminnow.
This cyprinodontid is common in the lower sections, preferring heavily vegetated backwaters along the shoreline away from the main current. Wiley and Hall (1975) recently recognized members of the Ouachita River population of the starhead topminnow as belonging to a separate species, *Fundulus dispar* (Agassiz); however, we will await further study before altering presently accepted nomenclature.

Fundulus notatus (Rafinesque). Blackstripe topminnow.
The same ecological separation noted by Braasch and Smith (1965) was documented in this study as *F. notatus* was collected only from the extreme lower portions of the system in Moro Bay, while *F. olivaceus* was abundant in the upper and middle three-fourths of the system. The two species were never collected syntopically in Moro Creek. Pflieger (1971) noted similar ecological preferences in Missouri for these two sister species.

Fundulus olivaceus (Storer). Blackspotted topminnow.
More common than *F. notatus*, the blackspotted topminnow was found throughout the upper and middle regions in quiet pools and the edges of the main current.

Poeciliidae (Mosquitofishes)

Gambusia affinis (Baird and Girard). Mosquitofish.
Widespread and abundant pool resident throughout the system.

Atherinidae (Silversides)

Labidesthes sicculus (Cope). Brook silverside.
Common and abundant throughout Moro Creek, particularly in pools.

Aphredoderidae (Pirate Perches)

Aphredoderus sayanus (Gilliams). Pirate perch.
Widespread slackwater inhabitant favoring heavily vegetated stream edges.

Centrarchidae (Sunfishes)

Centrarchus macropterus (Lacepede). Flier.
Several adult fliers along with characteristic juveniles were taken in the lower sand-bottomed pools where vegetation was abundant.

Chaenobryttus gulosus Cuvier. Warmouth.
Following Miller and Robison (1973), the name *C. gulosus* is retained for the warmouth. The warmouth exhibited a decided preference for lower stream areas in mud-bottomed pools with rooted aquatic vegetation.

Lepomis cyanellus Rafinesque. Green sunfish.
With its rather plastic habitat requirements, the green sunfish occurs throughout the system. Most widespread centrarchid in Moro Creek.

Lepomis humilis (Girard). Orangespotted sunfish.
Buchanan (1973:Map 143) reported a single record of this species from Moro Creek; however we did not collect *L. humilis.*

Lepomis macrochirus Rafinesque. Bluegill.
Widespread and abundant in the system, especially near the confluence with the Ouachita River where abundant cover was available.

Lepomis marginatus (Holbrook). Dollar sunfish.
The most common centrarchid of the lower sections near Moro Bay. Extremely common in larger pools through which flowed a moderate current and also in backwater pool margins.

Lepomis megalotis Rafinesque. Longear sunfish.
Buchanan (1973:Map 146) reported one record from the middle section of Moro Creek; however, we did not collect this species. This may actually be a misidentification of *L. marginatus*, a closely related species with which it is easily confused.

Lepomis microlophus (Gunther). Redear sunfish.
The redear was collected only twice during our survey from the lower stream sections. Probably prefers more lacustrine conditions than are available in Moro Creek.

Lepomis punctatus (Valenciennes). Spotted sunfish.
Confined to the lower sections in still, weedy, shallow backwater areas away from the main current. Relatively common.

Lepomis symmetricus Forbes. Bantam sunfish.
Taken only in dense vegetation in 2-5 ft. of water over sand substrates.

Micropterus punctulatus (Rafinesque). Spotted bass.
Most common bass in Moro Creek, although never found to be abundant.
Micropterus salmoides (Lacepede). Largemouth bass.
Rarely found except in the lower extremes of the stream near the Ouachita River where it is common.
Pomoxis annularis Rafinesque. White crappie.
Buchanan (1973:Map 154) reported one record. No crappie were collected during this survey.
Pomoxis nigromaculatus (Lesueur). Black crappie.
While this species was not collected in this survey, Buchanan (1973:Map 155) showed a single record.

Elassomatidae (Pygmy Sunfishes)

Elassoma zonatum Jordan. Banded pygmy sunfish.
Extremely widespread and abundant in weedy backwater and marginal areas of shallow pools.

Percidae (True Perches)

Etheostoma cholorosomum (Hay). Bluntnose darter.
Widespread darter preferring sand substrates in shallow pool areas.
Etheostoma collettei Birdsong and Knapp. Creole darter.
Quite common and abundant darter in Moro Creek in swift gravel riffles. Avoids the sluggish lower stream sections.
Etheostoma gracile (Girard). Slough darter.
This is the only percid reported by Buchanan (1973) not collected by us in Moro Creek.
Etheostoma histrio Jordan and Gilbert. Harlequin darter.
Rare in the system. Occurring over sandy substrates in 1-2 ft. of water with moderate current.
Etheostoma proeliare (Hay). Cypress darter.
Widespread and abundant percid of weedy backwater areas. This species was the most abundant percid in the system.
Etheostoma stigmaeum (Jordan). Speckled darter.
The speckled darter was collected only in Jack's Creek where the population was uncommonly darkened due to the blackened substrate occurring there.
Etheostoma whipplei whipplei (Girard). Redfin darter.
The nominal form of the redfin darter was common in the smaller tributaries of Moro Creek, although it occurred commonly in the main stream in riffles and sandy-bottomed shallow pools through which flowed a moderate current.
Percina caprodes (Rafinesque). Logperch.
Rare in the system, probably preferring higher gradient stream sections than are present in most of Moro Creek. Taken only at Stations 8 and 9.
Percina maculata (Girard). Blackside darter.
Rare. A single specimen taken from a two ft. swift gravel bottomed section of Moro Creek below the large pool at Ark. Hwy. 160 bridge where the man-made pool narrows to form the small main channel.
Percina sciera (Swain). Dusky darter.
Most common *Percina* species in Moro Creek. Occurring in swift flowing sections over sand bottoms where twigs, leaves, and debris form protected microhabitats in the stream channel.

DISCUSSION

Sixty-three species of fishes representing 14 families were collected from Moro Creek during this study. In addition, eight species not taken by us but known from the creek were reported by Buchanan (1973). Cyprinids and centrarchids were numerically dominant with 15 and 14 species collected, respectively. Ten percid species taken attest to the relatively good water quality of Moro Creek. The number of species in Moro Creek generally increased from headwater to lower stream reaches. Such a longitudinal increase in species has been previously well documented in stream fishes (Jenkins and Freeman, 1972; Stauffer, et. al., 1975; and Hocutt and Stauffer, 1975).

Fishes collected from Moro Creek proved to be typical of the central Coastal Plain ichthyofauna of Arkansas. One undescribed species, the bluehead shiner, was documented from Moro Creek for the first time, but this shiner occurs in adjacent areas of Moro Creek, thus the discovery was not unexpected.

While for most of its length Moro Creek varies from 6-12 ft. wide, at Ark. Hwy. 160, earth has been removed in sufficient quantities to provide roadbed material thus creating a large lentic habitat quite unusual for Moro Creek where such lacustrine species as *Dorosoma cepedianum, D. petenense, Minytrema melanops, Amia calva, Lepisosteus oculatus* and others were collected. Small, sluggish Coastal Plain streams typically lack such large lentic habitats. That such lacustrine species may increase in abundance in the future is supported by a confirmation by R. P. Flanagan (pers. comm.) that the new Felsenthal Lock and Dam now under construction on the main Ouachita River when completed will result in the slackwater pool moving "a small distance up the mouth of Moro Creek." Undoubtedly, Moro Bay, an oxbow of the Ouachita River serves as a prime stocking source for Moro Creek, replenishing fish stocks following low water levels and it accounts in part for the high species diversity (63 species) encountered in Moro Creek. Moro Creek appears to occasionally support a number of large river species, including *Ictiobus cyprinellus, Notropis atherinoides, N. buchanani,* and *Pomoxis* spp., which are generally found in the Ouachita River. These may be strays or waifs, or could possibly utilize the resources of Moro Creek at various periods during the year following periods of low productivity, floods, or a host of other factors.

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Structural Geology of the Brentwood-St. Paul Area, Northwest Arkansas

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ABSTRACT

Photogeologic and field mapping of a 530 mi² area in southeastern Washington and southern Madison Counties, Arkansas, indicates that post-Atoka structural deformation occurred primarily through differential uplift of basement fault blocks. Northeast and east trending basement faults and fracture systems are present. Northeast trending features are related to the major fracture systems of the stable continental interior. They were initiated by shearing during Pre-Cambrian time and have subsequently acted as crustal zones of weakness along which mostly vertical movement has occurred. East trending basement faults may have originally developed as a result of tension between the stable Ozark uplift and the subsiding Arkoma basin during late Atokan time. Northeast and east trending faults join to form a mosaic of polygonal basement blocks. During post-Atoka uplift(s) of the Ozark region, each block behaved more or less independently. Normal faults and (more commonly) monoclinal draping occurred in the sedimentary rocks which overlie the marginal basement fault zones. Slight tilting and warping of the blocks created local homoclinal dips whose magnitude and direction may change abruptly at block margins. Structural highs occur at the most elevated margin or corner of each block.

Horizontal compression during the Ouachita orogeny possibly accounts for several gentle east trending folds in the Pettigrew area. An anomalous dome structure near Witter may be related to a local high on the Pre-Cambrian basement surface.

INTRODUCTION

The northern Boston Mountain area of northwest Arkansas has undergone mild structural deformation. Broad expanses of nearly flat-lying beds are broken by small-displacement faults and monoclines. Low amplitude anticlines and shallow synclines occur locally. Mapping of these structural features has been hindered previously by a lack of large-scale topographic base maps and by an apparent lack of mappable stratigraphic units in the widespread Atoka Formation. Recent publication of 7½-minute topographic quadrangles, in combination with the recognition of three widely mappable sandstone units in the lower Atoka, now permit detailed geologic mapping (Hoover, 1976; Kelley, 1977; Shinn, 1977).

This study is a description of the magnitude, orientation and spatial relationships of structures occurring within a relatively large area in the northern Boston Mountains. These features form a pattern which suggests that regional tectonic deformation has occurred primarily through differential uplift and tilting of large crustal blocks. Horizontal compression has played a relatively minor role in the development of this regional pattern.

LOCATION

The name Brentwood-St. Paul area is applied to a 530 mi² area in northwest Arkansas which includes all or most of T. 13-15 N., R. 25-29 W. The area lies primarily within southeastern Washington and southern Madison Counties. Small portions of northern Crawford, Franklin and Johnson Counties are also included. Topographic relief within this area is moderate to rugged. Elevations range from about 1000 feet to over 2500 feet. Differential erosion of nearly horizontal sandstone and shale units has created a characteristic bench and bluff topography.

PREVIOUS INVESTIGATIONS

The westernmost portion of the study area was originally mapped by Simonds (1891) and Purdue (1907) who each reported minor structural deformation. In master's thesis investigations by Kimbro (1960), Bishop (1961), McEntire (1964) and Phifer (1967), elements of the northeast and east trending fold series described by Quinn (1959) were reported in the Brentwood-St. Paul area. No evidence supporting the existence of these structures was found in the present investigation.

Middle Bloyd stratigraphy and structure of the Witter area (Madison County) has been described recently by Berry (1978). Kelley mapped lower Atoka units in southeastern Washington County (1977).

METHODS

The Brentwood-St. Paul area was mapped primarily through photogeologic techniques. These techniques are similar to those employed by Desjardins and Hower (1939) and Nugent (1947) in mapping areas of gently dipping strata, and were used recently in a study of the structure of southern Washington and northern Crawford Counties (Shinn, 1977).

Three ledge-forming sandstone units in the lower Atoka Formation were identified and traced throughout the area on stereoscopic aerial photography. The positions of the units were then transferred to 1:24,000 scale topographic quadrangles. Systematic changes in elevations of mapping units result from subtle structural deformation. Structural features were described through the preparation of structure contour maps of the tops of the first and third Atoka sandstones, employing a 40 foot contour interval.

Field investigations were used to aid and confirm photographic interpretation. Fifteen measured sections were made of the upper Bloyd and lower Atoka Formations, using an altimeter and hand level. Additional field studies were concentrated in areas of relative structural complexity, particularly along the Drakes Creek structural lineament.

STRATIGRAPHY

The Pre-Cambrian igneous basement of the Brentwood-St. Paul area is overlain by a maximum of approximately 4000 feet of Paleozoic sedimentary rocks. Most pre-Pennsylvanian rocks are carbonates. The Pennsylvanian Hale, Bloyd and Atoka Formations are predominantly composed of sandstone and shale. In this study, structural fea-

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tures were delineated by observing elevation changes of the tops of three sandstone units in the lower Atoka Formation. The units are blanket deposits of thin- to thick-bedded, very fine- to fine-grained quartzarenite which probably formed through seaward progradation of beach-barrier island complexes (Hoover, 1976). The sandstone units are separated by shale intervals which record episodes of marine transgression. Figure 1 is a stratigraphic section which illustrates the lateral persistence of the Atoka sandstone and shale units within the northern portion of the study area. In southeastern Washington County, the underlying Trace Creek Member of the upper Bloyd Formation is composed entirely of black shale and siltstone. In Madison County one or more prominent sandstone units occur within the Trace Creek. These upper Bloyd sandstones apparently extend into Franklin and Johnson Counties where, in the subsurface, they have hitherto been recognized as lower Atoka units (Corbin, thesis in preparation).

STRUCTURAL GEOLOGY

The Brentwood-St. Paul area lies on the southern margin of the east trending northern Arkansas structural platform (Chinn and Konig, 1973). Regional southerly dip is nearly zero across the platform. The north flank of the Arkoma basin begins along a series of down-to-the-south faulted monoclines a few miles south of the present study area.

Structural Features

Structural features within the Brentwood-St. Paul area exhibit two preferred orientations. Most folds and faults trend either approximately N30E or due east (Figure 2).

Extensive northeast trending lineaments are evident on satellite imagery of the Arkansas and Oklahoma Ozarks. Most of these topographic features are directly related to lines of tectonic disturbance and thus may accurately be called "structural lineaments" (Hodgson, 1965). At least three such lineaments are present in the Brentwood-St. Paul area. From west to east, these features are designated the Drakes Creek, Combs and Venus structural lineaments.

The surface expression of the structural lineaments is related to closely-spaced fractures, normal faults, monoclines, synclines or a combination of these features. Fault displacement and overall structural relief may vary markedly along the lineaments. This variation is commonly due to the presence of discontinuous synclines on the downthrown sides of faults and monoclines. Structural relief varies in a more systematic fashion where east trending faulted monoclines meet with the northeast lineaments. For example, fault displacement on the Drakes Creek lineament decreases from over 300 feet just east of Durham (T15N, R28W) to zero in T13N, R29W, south of Brentwood. Between these two areas the east trending, down-to-the south Brentwood faulted monocline joins the Drakes Creek lineament from the west. A similar down-to-the-south tensional zone (Dutton faulted monocline) extends east between the Combs and Venus lineaments. North of this zone, the Combs lineament is expressed as a monocline which dips northwest at approximately one degree. South of the Dutton structure, the sense of displacement along the Combs lineament is reversed and is to the southeast. Deformation along the Venus lineament takes the form of a syncline and a down-to-the-northwest monocline to the north and south of the Dutton structure, respectively. Dips on the monocline range from 1 to 3 degrees.

Synclines along the northeast trending lineaments are usually associated with faults and monoclines, but may occur alone, locally. These features are most prominently developed along the Drakes Creek structural lineament. A structural low which occurs on this trend in T13N, R29W is accompanied by secondary faulting. Another broad downwarp occurs along the Drakes Creek lineament in T15N, R27W.

Anticlines with northeast trends occur intermittently along the major lineaments. These features are most strongly developed on both sides of the Venus lineament in T14N, R25W (Ogden Creek and Boston anticlines). Flank dips on these two structures average 1.5 degrees. The highest structural elevation in the area occurs along the axis of the Boston anticline.

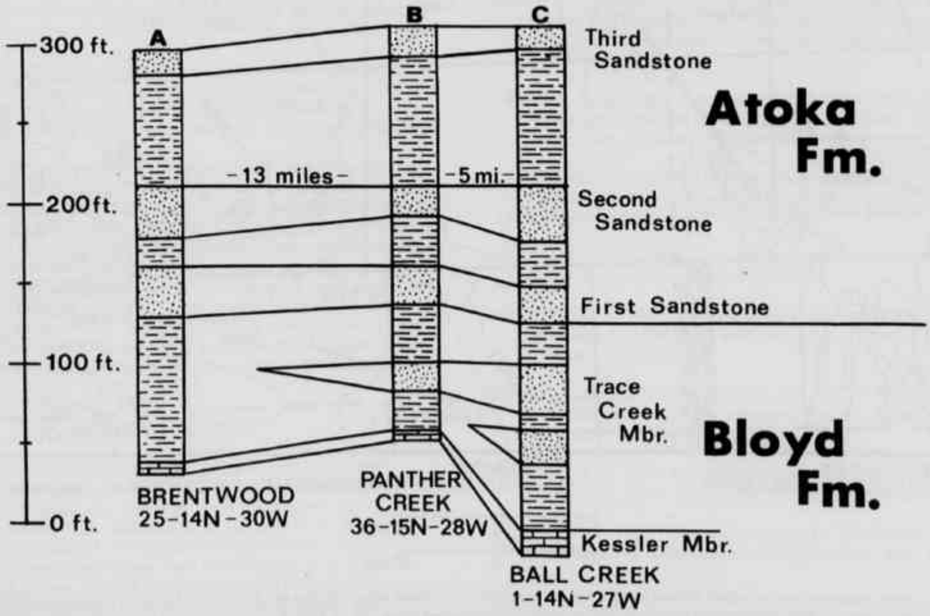

Figure 1. Correlation of selected measured sections in the upper Bloyd and lower Atoka Formations (Pennsylvanian), southeastern Washington and southwestern Madison Counties, Arkansas. Datum is top of second Atoka sandstone. Locations of sections are shown on Figure 2.

Two anticlines which lie just east of the Combs lineament in T14-15N, R26W have a northeasterly alignment, but are not clearly related to other features associated with that trend. Precise delineation of the structure near Witter (T15N, R26W) is hampered by the absence of the lower Atoka in most of the area. This feature is apparently a broad northeast trending arch upon which a small, well defined dome is superimposed. Total structural relief is approximately 100 feet. The structure in T14N, R26W is an isolated dome with a structural closure on the third Atoka sandstone of less than 50 feet.

The major east trending structures of the area are the Brentwood and Dutton faulted monoclines. Both features are at least 7 miles long and lower strata to the south about 150 to 200 feet. Although each structure is basically a monoclinal flexure, both are locally broken by normal faults having displacements of 40 to 160 feet. Individual faults, which do not exceed 2 miles in length, succeed each other along strike. A westward plunging syncline and accompanying structural nose occur at the west end of the Brentwood faulted monocline in the west half of T14N, R29W. The faulted monoclines terminate against the major northeast trending structural lineaments. Strike directions on the monoclines shift to the northeast in proximity to the major lineaments.

A series of east trending folds occurs in T13N, R25-26W. The folds are symmetrical, with flank dips of from 0.5 to 1.5 degrees. The structures cross a down-to-the-northwest monocline on the Venus structural lineament. Dip magnitudes along the monocline are great enough to largely obscure the east trending folds within the zone of intersection. Distinct domes and basins have thus formed along the anticlinal and synclinal trends on opposite sides of the Venus lineament. These folds do not extend west of the Combs lineament.

Persistent dips of less than 0.5 degrees prevail across large portions of the Brentwood-St. Paul area. The direction and magnitude of these homoclinal dips tend to change at the major structural lineaments and east trending faulted monoclines. On the upthrown sides of the Drakes Creek fault and Brentwood faulted monocline, beds dip slightly to the west-northwest. South of the Brentwood structure, beds dip generally to the southwest. Except for prominent local downwarps near the Drakes Creek structure, strata are nearly horizontal across the large area between the Drakes Creek and Combs lineaments. Between the Combs and Venus lineaments, beds again dip generally to the west-northwest.

Origins of Structural Features

Northeast trending structural lineaments are the dominant elements of the regional structural pattern in the Brentwood-St. Paul area and throughout the northern Boston Mountains. The orientation of these features suggests that they originated through shearing as a result of northward directed stresses. Smith (1977) presented geophysical evidence of a basement shear zone (without normal faulting) along the Ponca lineament in Newton County. Northward directed stresses associated with the Ouachita orogeny would presumably account for the creation of the lineaments. McKnight (1935, p. 91) showed, however, that vertical movement occurred along at least one of the major northeast lineaments as early as Devonian time, thus demonstrating their existence prior to the Ouachita orogeny. A source for tectonic stresses capable of creating such structures is not known in earlier Paleozoic time. Thus a Pre-Cambrian time of origin for the features is indicated.

The northeast trending structural lineaments probably originated through shearing of the igneous basement rocks during late Pre-Cambrian time. Later, these features acted as zones of crustal weak-

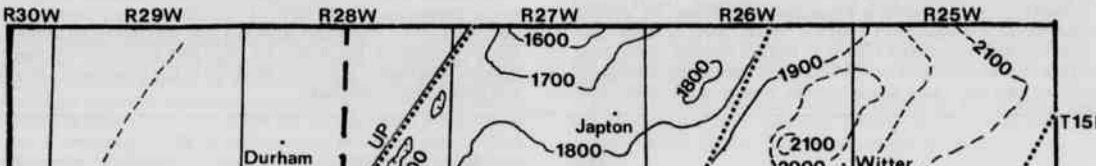

Figure 2. Structure contour map of third Atoka sandstone in Brentwood-St. Paul area, northwest Arkansas. Contour interval is 100 feet. Where contour lines are dashed, third Atoka sand is absent and mapping is projected from top of first Atoka sandstone. Asterisks designate locations of measured sections A, B and C (Figure 1). Encircled numbers designate the following structural features: 1 - Brentwood faulted monocline; 2 - Dutton faulted monocline; 3 - Ogden Creek anticline; 4 - Boston anticline.

ness along which the effects of deforming stresses were concentrated. During periods of uplift related to the formation of the Ozark dome, normal faulting probably occurred along these ancient basement fracture zones. In most areas, differential uplift along the basement faults resulted only in monoclinal flexing of the overlying sedimentary beds. Where extension was excessive, however, high angle normal faults formed in the overlying sedimentary rocks. The Drakes Creek fault may be a good example of this relationship.

The northeast trending basement fracture zones controlled the extent of the younger, east trending Brentwood and Dutton faulted monoclines. At the level of the Pre-Cambrian basement these structures probably occur as one or more well-defined faults. Monoclinal draping and intermittent faulting in the overlying sedimentary rocks are reflections of the more pronounced underlying features. The Brentwood and Dutton structures are similar to other east trending faulted monoclines on the north flank of the Arkoma basin. They probably originated as a result of extension between the stable Ozark uplift and the subsiding basin during late Atokan time. Additional relative movement may have occurred during periods of post-Atoka uplift.

The northeast and east trending basement fault zones join to form a mosaic of polygonal crustal blocks. Each major basement fault block behaved more or less independently during post-Atoka regional uplifting. The direction and magnitude of dip on the broad homoclines, which occur between structural lineaments, reflect slight tilting of the individual blocks. Northeast trending structural highs occur at the most elevated margin or corner of each block. Previously, the origin of northeast trending structural lows developed along the trace of the lineaments has been ascribed to subsurface solutioning and removal of carbonate rocks, with subsequent subsidence (Quinn, 1963). Another possible explanation, which may account for the broader synclinal nature of these features, is that slight local divergence of fault blocks has occurred along the northeast trending lineaments. Such divergence might arise through stretching of the crust during regional vertical uplift. Downwarping and secondary normal faulting would presumably occur along the block margins in response to tensional stresses created by the divergence. The net result of this structural adjustment would be the formation of a gentle structural "sag" overlying the join between the two adjacent fault blocks. More recent solutioning of subjacent carbonate rocks, as proposed by Quinn (1963) would account for the more local features (subsidence structures) that occur within the earlier formed syncline.

The east trending folds in the Pettigrew area (T13N, R25-26W) possibly formed in response to northward directed stresses of the Ouachita orogeny. The extent of the fold belt appears to have been controlled on the west by the presense of the Combs structural lineament.

The origin of the dome structures east of the Combs lineament in T14-15N, R26W cannot be explained easily in terms of basement block faulting, nor can they be readily related to compressive stresses associated with the Ouachita orogeny. Croneis (1930, p. 189) noted that a well on the east flank of the high near Witter penetrated basement rocks at an unexpectedly shallow depth. A local topographic high on the Pre-Cambrian surface is thus indicated. Such buried hills often underlie surface anticlines in the sedimentary rocks elsewhere in the Mid-Continent area. The mechanism whereby upward reflection of the buried hills occurs is not well understood, although differential compaction of sediments across the hills has been suggested (Blackwelder, 1920).

ACKNOWLEDGMENTS

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Methodology for Analysis of Diet Grit Size on Molar Attrition for Fourche Maline and Caddo People

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ABSTRACT

Using the Murphy (1959) system for scoring the degree of dentin exposure, Fourche Maline (Woodland) molars show a greater attrition rate than Caddo (Mississippian) molars. Archeological evidence suggests that this differential in attrition rates is caused by the use of stone grinders for food preparation in the Fourche Maline culture and their absence among the Caddo. Analysis of scratches on the occlusal surface of molars from these samples confirms this hypothesis. Several techniques for observing these scratches and reconstructing the grit sizes and grit particle frequencies responsible for this differential abrasion are evaluated.

INTRODUCTION

The reconstruction of prehistoric diets for some time has been of interest to both archeologists and biological anthropologists. One important aspect of this reconstruction is a consideration of the effects of consistency of diet and various food processing techniques on the rate of dental attrition. For example, Dahlberg (1960) reports the rapid dental attrition of Neolithic agriculturalists, and others note a decline in attrition rates as food preparation techniques improve (Armelagos and Rose 1972; Molnar 1971). Walker (1976) demonstrates that the prehistoric inhabitants of Santa Rose Island had greater dental attrition rates than the inhabitants of the California mainland. This increased rate is attributed to the islanders' maritime adaption and the sand and grit associated with seafood.

This study is concerned with reconstruction of the dietary consistency of the Fourche Maline (ca. 500 B.C.-800 A.D.) and Caddo (ca. 800 A.D.-1550 A.D.) cultures of western Arkansas and eastern Oklahoma. McWilliams (1970) states that the Fourche Maline focus (considered Middle Woodland) probably represents a peripheral survival of a southeastern U.S. Archaic hunting and gathering complex. Burials were interred in midden areas containing large quantities of fresh water mussel shells and animal bones, but no evidence of cultigens. Collected plant food was prepared in stone grinders commonly found at Fourche Maline sites. Caddo subsistence patterns include maize agriculture in addition to the harvesting of wild plants and hunting. Stone grinders are notably absent from Caddo sites, and it is assumed that wooden mortars were used in food preparation (Swanton 1942: 131, 134). The use of these wooden mortars would not be expected to contribute as much grit to the diet, and this should be reflected in dental attrition rates. It is this assumption, that the Caddo did not use stone grinders for food preparation, which is tested in this study.

DENTAL ATTRITION

The Fourche Maline sample consists of 18 individuals aged between 18 and 30 years from the Sam and Wann sites in eastern Oklahoma. The Caddo sample consists of 22 individuals aged between 18 and 30 years from 8 Caddo sites in southwestern Arkansas. Attrition rates were determined using the Murphy system (1959) which assigns each tooth a numerical value (1-8) based on the progressive exposure of dentin on the occlusal surface of the molar. This system allows computation of the mean attrition stage for each molar as well as the attrition gradient. The attrition gradient is defined as the difference in attrition between the first and second, and the second and third molars as a result of differences in eruption time.

The mean attrition scores for the Fourche Maline sample are 6.9, 5.4 and 1.9 for the first, second and third mandibular molars respectively. The attrition gradient is 1.5 and 3.5. The mean attrition scores for the Caddo sample are 2.5, 1.5 and 0.36 for the first, second and third molars respectively. The attrition gradient is 1.0 and 1.1. The Fourche Maline dental attrition rate is twice that of the Caddo sample, appearing to support the assumption that the Caddo did not use stone grinders in food preparation. The data, however, only establish that there are differences in attrition rates; it does not provide information on the consistency of the diet. To establish differences in the consistency of the diet, a microscopic analysis of the occlusal surfaces of mandibular molars was attempted.

MATERIALS AND METHODS

Optimally, this type of analysis is performed with the scanning electron microscope as reported by Shkurkin and co-workers (1975). However, this procedure is expensive and is not feasible for routine analysis. Consequently, the following techniques were tried in order to observe the attrition or abrasion pattern of human enamel.

Five mandibular molars were selected from both the Roden and Mahaffey skeletal collections. The Roden collection represents the Caddo tradition, and the Mahaffey collection represents the Fourche Maline. Both sites are from eastern Oklahoma and exhibit attrition rates comparable to the skeletal series reported above. After cleaning in a sonic cleaner with 95% ethanol for two hours, each tooth was mounted on a slide with beeswax so that the occlusal surface would be as parallel to the microscope as possible.

After a number of attempts to make peels of the occlusal surface (e.g., using various concentrations of acetate and acetone) it was found that the best results involved photographing the occlusal enamel surface through a Zeiss universal microscope with reflected nomarski differential interference contrast optics. Four flat areas of each tooth were photographed at 160 magnifications, with Panatomic X 35mm film developed at 100 ASA. The negatives were printed on 8 x 10 paper at an enlargement of 10X. Counts and measurements of the scratches were taken directly from these prints. Scratch widths were measured with a needle point Helios dial caliper to the nearest tenth of a millimeter. Counting procedures utilized a Weibel linear grid pattern of 15 lines each 4cm long, scribed on an acetate sheet which was laid over each photograph. Any scratch intersecting a scribed line was counted.

RESULTS

General observations of the photographs of the 10 teeth in the sample showed some differences between the two cultures. Both Roden and Mahaffey teeth show a quiltwork pattern of short narrow scratches characteristic of all human tooth wear. On the Roden teeth these scratches are overlain by a random pattern of long deep scratches varying in frequency per photograph from none to many. The Mahaffey teeth also contain deep scratches varying from moderate to many on all photographs with much of the quilt pattern being obliterated.

The best photograph of each tooth in the sample was chosen for total scratch counts. All scratches intersecting the 15 lines in the

Weibel grid were tabulated, and mean frequencies per 4cm grid line were calculated (Table 1). The mean frequencies and variances were not significantly different within each culture. However, a mean abrasion frequency for the five Caddo teeth of 9.6 as compared to 14.0 for the Fourche Maline molars is significant at the five percent level using a one tail student's t statistic.

The apparent differences between the patterning of abrasions as caused by large particles was then investigated. The widths of the 17 largest abrasions were measured for both samples, which resulted in mean widths (as measured on the prints) of 3.4mm for Fourche Maline and 3.6mm for Caddo. This would suggest that there is no real difference in particle size between the two cultures. The smaller abrasions (less than 1mm in width) are not reliably measured. The frequency of large abrasions (at least 1mm in width) was tabulated for each tooth (Table 2) using the Weibel grid and averaging the total grid scores from the four photographs of each tooth. The Fourche Maline teeth have over twice the abrasions ($\bar{m}=25.0$) as the Caddo teeth ($\bar{m}=10.3$). These differences are significant at the one percent level (student's t).

Table 1. Mean frequency of abrasions per 4cm Weibel grid line

FOURCHE MALINE		CADDO	
MOLAR	MEAN FREQ.	MOLAR	MEAN FREQ.
m40-1	13.3	r2-b	7.7
m4	17.9	r1-a	10.8
m58h	16.7	r1-b	13.2
m2	14.3	r1-c	8.0
m40-2	8.0	r18	8.1
mean	14.0	mean	9.6

Table 2. Mean frequency of abrasions larger than 1mm for Fourche Maline and Caddo molars

FOURCHE MALINE		CADDO	
MOLAR	MEAN	MOLAR	MEAN
m40-1	41.8	r2-b	11.0
m4	21.8	r1-a	21.8
m58h	22.2	r1-b	9.2
m2	18.2	r1-c	7.8
m40-2	21.2	r18	11.0
mean	25.0	mean	10.3

DISCUSSION

The attrition rate data demonstrate that the Fourche Maline suffer more than twice the tooth loss due to abrasion than do the Caddo. This greater attrition rate can be attributed to either a greater frequency of particles in the diet and/or the inclusion of larger particles in the diet. An examination of the total abrasion counts indicate that the Fourche Maline have a slightly greater frequency of observable abrasions, which indicates an increase in particle frequency in the 0.5 to 5.0 micron range. Particles of smaller dimensions would not leave abrasions observable by this technique (verified with standard thin section abrasives). For the 5 micron and greater range of particle sizes, the Fourche Maline have more than twice the abrasions of the Caddo. This greater number of the larger abrasions in the Fourche Maline sample indicates that at least part of the greater attrition rate can be explained by an increased frequency of these larger particles in the diet.

Dental attrition of dietary origins results from the abrasions of coarse foods such as roughly milled grains. All people also suffer to some extent from abrasion due to accidentally introduced sand and grit in the diet. Due to the many similar ecological and cultural conditions for the Fourche Maline and Caddo cultures, this grit content might be expected to be similar for both groups. However, the use of stone manos and metates for grinding grains provides an excellent source for numerous fine particles (not observable in this study) as well as numerous larger particles of silicon to be introduced into the diet. The rapid attrition of metates from use in grinding grain is easily observed in archeological specimens. If the assumption is correct that the Caddo utilized wooden mortars for pounding grains the frequency of large particles in the diet should be significantly smaller than the frequency for the Fourche Maline peoples. This initial research demonstrates a significantly lower frequency of the larger particle sizes in the Caddo diet.

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The Influence of Lead, An Environmental Pollutant on Metamorphosis of *Rana utricularia* (Amphibia:Ranidae)

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ABSTRACT

The influence of lead, an environmental pollutant on metamorphosis of *Rana utricularia*, was examined in this study. Larvae of stage XI (Taylor and Kollros, 1946), beginning of the premetamorphic stage, were exposed to lead concentrations of 0.1 ppm, 0.5 ppm, 1.0 ppm and 1.5 ppm for 106 days. The untreated larvae served as controls. Larvae were observed from early limb bud stage, stage X, through the protrusion of the forelimbs, stage XX. Neither the sequence of developmental events nor the gross external and internal morphology was altered by lead. However, lead prolonged the time of metamorphosis by delaying the completion of each successive prometamorphic stage. The extent of delay was concentration dependent. The thyroid gland of the experimental larvae underwent alterations which were also concentration dependent. The size of the gland and the size of the follicle were reduced. Vacuolation occurred in the colloid of both 0.5 ppm and 1.5 ppm lead treated larvae.

INTRODUCTION

Lead is one of the environmental pollutants which has become more prevalent due to mechanization and industrialization. Lead particles enter the atmosphere from leaded gasolines, pesticides, manufacturing, combustion of coal, incineration of refuse, and leaded paints (Pagenkoff and Neuman, 1974). Lead mining industries are another source of environmental contamination. The lethal effect of environmental lead on organisms was first reported by a lead-polluted stream to the presence of the metallic salts dissolved in the water. Investigations concerning metallic pollutants have focused on various invertebrates and vertebrates as indicator organisms for toxicologic study; the toxicity of lead has been demonstrated in both embryonic and adult forms of bivalves (Eisler, 1977), in zooplankton (Baudouin and Scoppa, 1974), in birds (Benson et al., 1974 and Benson et al., 1976) and in tadpoles (Bell, 1924). Sublethal efects of lead also have been documented in man and other vertebrates (for review, see National Academy of Science, 1972), but few investigators have considered long term effects due to lead from environmental sources on developing organisms.

Metamorphosis is a developmental phenomenon frequently associated with a change in habitat by an organism, such as from an aquatic habitat to a terrestrial habitat by frogs and toads. Adaptation to a new environment requires considerable transformation of both structure and function in the living organism (Berrill, 1971). These transformations are considered to be related directly to the activity of the thyroid (Lynn and Wachowski, 1951). Significant alterations of the environment might be expected to complicate developmental processes, such as metamorphosis, and possibly to alter morphological and histological development of the organism.

Since the effect of lead on metamorphosing organisms has not been documented, this experiment was designed to examine the influence of lead on metamorphosing larvae of amphibians. *Rana utricularia* was chosen as the experimental animal because of its availability and relatively short metamorphic period, two to three months. Particular attention was paid to the time required for the completion of the events of each stage of metamorphosis, the sequence of metamorphosis, and normalcy of morphological changes. Finally, since the function of the thyroid may be altered by the action of lead, this possibility was approached indirectly by examining the histology of the thyroid gland.

MATERIALS AND METHODS

The larvae of *Rana utricularia* were collected from a shallow pond near Lake Wedington in Washington County, Arkansas, in early May. The larvae were reared in the laboratory at a density of five organisms per liter of spring water which had a lead concentration of five parts per billion. Water temperature was maintained at 21°C ± 1°C and the water was changed every other day. The larvae were fed cooked leaf lettuce. Eight larvae, in two replicate groups of four larvae each, were exposed to one liter of lead nitrate, dissolved in spring water, at concentrations of either 0.1 parts per million, 0.5 ppm, 1.0 ppm or 1.5 ppm. One group, consisting of eight untreated larvae, were used as the initial control animals. However, the entire group died within eight days of unknown causes. Consequently, the 0.1 ppm lead treated larvae were substituted as the control group since this concentration is permitted in drinking water. The larvae were observed from early limb bud stage, stage X, through the protrusion of the forelimbs, stage XX (Taylor and Kollros, 1946). Observations were made over a period of 106 days.

In a second series of experiments, two organisms of stage XI (Taylor and Kollros, 1946) were exposed to each experimental concentration of lead nitrate for one week. Stage XI was chosen because it is the beginning stage of prometamorphosis. The larvae were fixed in 50% Bouin's fluid (Carleton and Drury, 1957) for 18 hours at 5°C ± 1°C (Berson, 1972). The head portions were subjected to standard histological preparation and stained with Periodic acid-Schiff and counterstained with Mayer's hematoxylin and eosin (Humason, 1972). Serial sections of the thyroid were studied by light microscopy.

The time required for metamorphosis was expressed as days ± the standard deviation. The significance of the difference between the time required for metamorphosis at different lead concentrations was determined by the student's T test (Simpson et al., 1960).

RESULTS

Lead, at the experimental concentrations, did not alter the sequence of metamorphic stages in *Rana utricularia*. All larvae exposed to experimental concentrations of lead exhibited normal gross external and internal morphology.

The time required for the completion of each successive metamorphic stage was altered, however, by different concentrations of lead (Figure 1). The 0.1 ppm lead treated larvae required 53.0 days to complete stage XX. The 0.5 ppm lead treated larvae required 55.7 days to complete development of stage XX. The 1.0 ppm lead treated larvae required 74.8 days to complete stage XX. The time required by 1.5 ppm lead treated larvae was intermediate (65.5 days) between the time required by 1.0 ppm lead treated larvae and 0.5 ppm lead treated larvae. The extent of delay was shown to be concentration dependent. The differences in time required to complete metamorphosis between the 1.0 ppm lead treated larvae and 0.5 ppm lead treated larvae was shown to be significant (P = 0.05 — 0.1) by the student's T test. The differences in time required to complete metamorphosis between 1.0 ppm and 1.5 ppm lead treated larvae and 0.5 ppm and 1.5 ppm lead treated larvae were statistically insignificant because of the insignificance of the difference of the means.

Examination of the serial sections of the thyroid gland revealed histological alterations attributed to lead. The extent of the alterations was also concentration dependent. In the control larvae, the shape of the thyroid follicles is spherical, and colloidal material completely fills the lumen (Figure 2). The epithelium is cuboidal and contains spherical nuclei. No black particles are seen in the epithelial cells of the control. The most extreme alterations of histological features occur in the thyroid of the 1.0 ppm lead treated larvae. Although the epithelium is normal, the follicles are poorly differentiated (Figure 3), and are completely devoid of colloidal material. The size of the thyroid also is reduced, and black particles appear in the gland. In the 0.5 ppm and 1.5 ppm lead treated larvae, the size of the thyroid is reduced but the shape of the follicle and the epithelium are the same as in that of the control. The colloidal material appears to have experienced some shrinkage and contains peripheral vacuoles (Figure 4).

DISCUSSION

In this experiment, *Rana utricularia* larvae of stage X were exposed to lead concentrations of 0.1 ppm, 0.5 ppm, 1.0 ppm, and 1.5 ppm for 106 days. No alteration in the sequence of metamorphosis or in gross external and internal morphology were observed. This result is in contrast to the finding that lead at a concentration of 1.0 ppm causes major defects in chick embryos at hatching Birge and Roberts, 1976). The defects in the chick included brain deficiencies, absence of eyes, skeletal anomalies, and severe motor impairment. Apparently these two species differ greatly in their susceptibility to lead.

Lead prolongs the time of metamorphosis by delaying the completion of each successive metamorphic stage (Figure 1). The extent of delay varies with different lead concentrations. The 1.0 ppm lead treated larvae required the most time to complete each metamorphic stage followed by 1.5 ppm, 0.5 ppm, and 0.1 ppm lead treated larvae. The amount of lead entering the system of the larvae has not been determined in this experiment, although evidence of the presence of lead in tissues is seen. Catizone and Gray (1941) working with chick embryos found no correlation between the strength of solution injected and the number and kind of abnormalities resulting in the central nervous system. In contrast to this, the teratogenesis in chick embryos is claimed by Birge and Roberts (1976) to be concentration dependent and to correlate inversely with survival. Therefore, it may be postulated that a mechanism, as yet undefined, exists, which could control the amount of lead entering the larvae. Since the transport of lead across biological membranes is largely lead concentration independent (Kostial and Momcilovic, 1974). The presence of such a mechanism could possibly aid in the explanation of the resistance to lead by the 1.5 ppm lead treated larvae.

The prolonging effect of lead was more prominent during the time of hindleg growth and development. The developmental rate of the larvae exposed to low concentration of lead, 0.5 ppm, shows that the rate of development is depressed until stage XIV, then the larvae produced through successive metamorphic stages at a faster rate. The developmental rate curves of the larvae exposed to high concentrations of lead, 1.0 ppm and 1.5 ppm, show that the rates were depressed much longer until stage XVIII. These results indicate that lead in high concentrations acts to delay metamorphosis by prolonging the time required for completion of the metamorphic stages, especially during development prior to stage XVIII.

Because of the involvement of the thyroid hormone, thyroxine, in metamorphosis, examination of thyroid histology was made to assess the effects of lead on the tissue. Considerable alteration was noted, many features of which resemble those seen in hyperthyroidism (Bloom and Fawcett, 1964). An expanded investigation of the effect of lead at successive stages of thyroid development is indicated.

Since the characteristics observed in the experimental thyroid, such as black particles, retarded development and vacuolation were not observed in the control, it can be said that these features are

Figure 1. Developmental rate curves of *Rana utricularia* larvae. x-0.1 ppm lead treated larvae; 0-0.5 ppm lead treated larvae; Δ-1.0 ppm lead treated larvae and -1.5 ppm lead treated larvae.

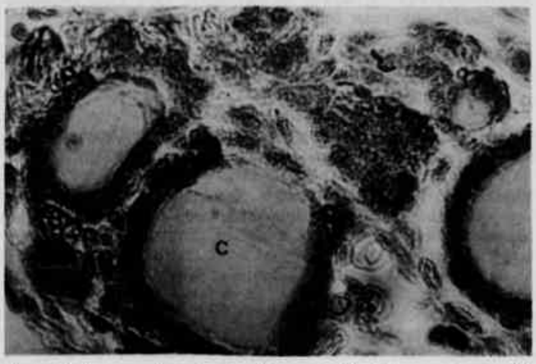

Figure 2. *Rana utricularia* thyroid, control-lead free; stained with alcoholic Periodic acid-Schiff, counterstained with Mayer's hematoxylin and eosin; magnification 375X, C-colloidal material; E-epithelium of thyroid follicle.

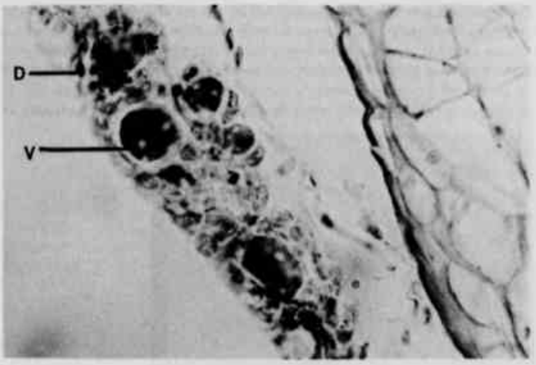

Figure 3. *Rana utricularia* thyroid, exposed to 0.5 ppm lead; stained with alcoholic Periodic acid-Schiff, counterstained with Mayer's hematoxylin and eosin; magnification 375X, C-colloidal material; D-dark particle; E-epithelium of thyroid follicle; V-vacuole.

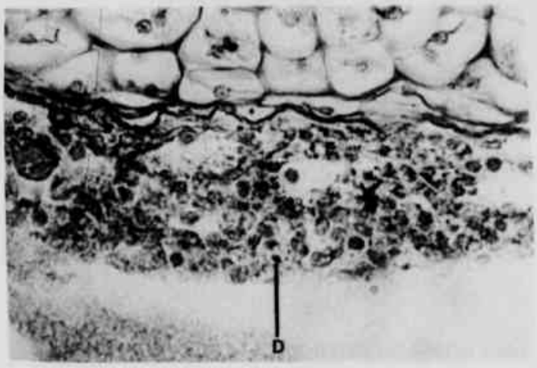

Figure 4. *Rana utricularia* thyroid, exposed to 1.0 ppm lead; stained with alcoholic Periodic acid-Schiff, counterstained with Mayer's hematoxylin and eosin; magnificantion 375X, D-dark particle; E-epithelium of thyroid follicle.

attributed to the action of lead. Lead had been shown to accumulate in fins, gills and liver of the fish (Merlini and Pozzi, 1977) and in kidney, bone and liver of *Xenopus* (Ireland, 1977). It is suggested that the dark particles seen in the thyroid may be lead in some form. The lead which appears to be deposited in the thyroid may impair the function of the thyroid which, in turn, delays metamorphic events. This suggestion is feasible since it has been shown that lead impairs thyroid function both *in vitro* and *in vivo* in rats and in man (National Academy of Science, 1972). *In vitro*, lead impairs the uptake of iodine^{131} by thyroid slices. Also, in lead poisoned rats, the poisoned rats, the uptake of iodine and the conversion of iodine to protein bound iodine are retarded. Therefore, one possible action of lead may be the impairment of iodine uptake. This possibility is further supported by the occurrence of vacuoles in the colloid of the thyroid of both 0.5 ppm and 1.5 ppm lead treated larvae. Similarly, vacuoles occur in the colloid of the thyroid of quails when the birds have been injected with prolactin (Wade et al., 1975). Prolactin has been found to lower significantly thyroidal iodine^{131} uptake in tadpoles (Gona, 1958). This hypothesis does not rule out, however, the possibility that lead also affects the hypothalamus and/or the pituitary which, in turn, may influence the thyroid and the event of metamorphosis.

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GENERAL NOTES

THE PRESENCE OF AN UNUSUAL EOSINOPHILIC STAINING SUBSTANCE IN THE BLOOD OF SNAKES

Telford (J. Florida Acad. Sci., 34:78-80, 1971) reported that certain Giemsa-stained blood smears from the lacertid, *Takydromos tachydromoides*, collected from Japan, had a peculiar staining reaction. Rather than the usual light bluish-gray background seen on such preparations, some smears had a reddish appearance. This reaction could be easily detected by macroscopic examination of the stained smear. Microscopically, this odd background material appeared to be precipitated between the blood cells and ranged in color from a light pink to a brick red. All blood smears with this reaction came from 41 female lizards that, with three exceptions, had developed yolk follicles to some degree. Telford concluded that the reddish precipitate resulted from lipid materials mobilized during vitellogenesis. Ayala and Spain (Copeia, 1975:138-141, 1975) confirmed and furthered these observations with *Anolis auratus* from South America. Complete correlation was seen between the appearance of the reddish-staining reaction on blood smears and oogenesis of autopsied female lizards. It was suggested that use of such a blood smear technique would allow the following of reproductive cycles in reptiles without permanent removal of animals from the environment. Ayala and Spain speculated that the precipitated material was probably lipoprotein that is found in reptile blood during yolk deposition. This conclusion was based on the data of Dessauer and Fox (Amer. J. Physiol., 197:360-366, 1959) from studies of plasma constituents of ribbon snakes undergoing oogenesis. The latter investigators were, however, unaware of the reddish-staining reaction of blood smears from oogenic reptiles with Romanowsky blood stains. To our knowledge, this highly eosinophilic material has not been isolated or chemically identified.

In a survey for blood parasites of 100 snakes collected from Lonoke County, Arkansas, in May and June of 1975, seven animals had this reddish staining reaction. Blood for smears was obtained either by decapitation or tailclipping and stained with Wright's using an Ames Hematek automatic staining machine. Positive blood specimens were found from three *Natrix erythrogaster* (yellow-bellied water snake), one *Natrix rhombifera* (diamond-back water snake), one *Natrix grahami* (Graham's water snake), one *Thamnophis proximus* (western ribbon snake), and one *Elaphe obsoleta* (black rat snake). As far as we can ascertain, this reaction has not been reported from any ophidians or other reptiles from North America. Unfortunately, the *E. obsoleta* (a female) was the only snake with positive blood smears that was sexed. It was kept in captivity and gender was determined at autopsy a year later. The reddish-staining reaction was discovered after the six other positive snakes had been discarded. Therefore, any relationship between the presence of the reddish substance and oogenesis in snakes is not yet established. In this regard, it should be noted that, with the exception of the black rat snake, all of the snakes in this report are live-bearers as opposed to the previous reports with egg-laying lizards.

The staining reaction on the blood smears of the seven snakes ranged from a light background to an intense, bright red. A comparison can be made between a smear with the normal very light, transparent stained plasma (Fig. 1A) and a smear with the most intense staining reaction of the precipitated material (Fig. 1B). Not previously noted is that the eosinophilic substance seems to accumulate more around the erythrocytes than the white cells. Since the nature of this reddish-staining material has been only conjecture, it would seem in order to isolate and chemically identify this unusual substance that has been previously associated with the plasma of oogenic lizards only. The finding of this material in such large and readily available ophidians such as water snakes would make obtaining reasonable quantities of this substance feasible for future studies.

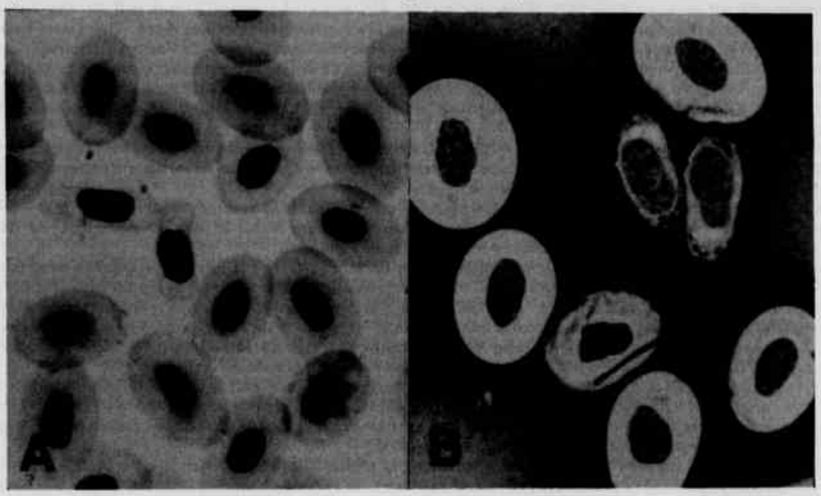

Figure 1. Blood smears stained with Wright's from *Natrix rhombifera* (A) with the usual transparent, lightly basophilic background and *Natrix grahami* (B) containing the eosinophilic-staining substance between the cells. Oil immersion (x1300).

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LONGEVITY OF WHITE BASS IN BEAVER RESERVOIR, ARKANSAS

A mark and recapture study to determine the movements of white bass, *Morone chrysops* (Rafinesque), in Beaver Reservoir, Arkansas, was conducted during the winters of 1967-68 and 1968-69. The recapture of four of these tagged white bass in 1974-76 produced new longevity records for this latitude. The oldest white bass previously recorded from southern United States waters (Center Hill Reservoir, Tennessee) was an 8-year-old (Webb and Moss, Proc. Annu. Conf. Southeast. Assoc. Game Fish. Comm. 21(1967):343-357, 1968). Beaver and Center Hill Reservoirs are at about the same latitude. Other localities where white bass 8 or more years old have been reported are: Oneida Lake, New York, 10 years (Forney and Taylor, N. Y. Fish Game J. 10:194-200, 1963); Spirit Lake, Iowa, 9 years (Sigler, Agric. Exp. Stn. Iowa State Coll. Res. Bull 366:236-244, 1949); and Shafer Lake, Indiana, 8 years (Riggs, Ph.D. Thesis, Univ. Michigan 224 p., 1953).

Three fish were 3-year-olds at the time of tagging; therefore one was an 8-year-old when recaptured in 1974, and two were 9 years old when recaptured in 1975. Total lengths at tagging were 315, 350, and 354 mm respectively. The last two fish listed establish a longevity record for white bass in the southern United States. One fish, 248 mm long was a 1-year-old when marked in November, 1968 and was over 8 years old when recaptured in 1976. Based on the angler's recapture report, the fish was 501 mm long and had gained about 900 g. Its weight at tagging was estimated from the average weight of several fish of the same length in a 1969 gillnet sample. This fish established a record for the length of time (7.6 years) a white bass has carried a tag.

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EFFECT OF LIMESTONE ON SPRING WEED POPULATIONS IN A FERTILIZED COASTAL BERMUDAGRASS SOD*

In 1968 a nitrogen-potassium fertilizer experiment was initiated at the Main Arkansas Agricultural Experiment Station to study the effects of these fertilizers on the yield and winter hardiness of Coastal Bermudagrass (*Cynadon dactylon* L.). Various research investigations have been conducted on this site dealing with the effect of fertilizer treatments on the yield and chemical composition of the forage, on the chemistry and acidity of the soil (Allured, 1976; Nagel, 1977), and on weed population and species. Allured et al. (1974) studied the effect of varying rates of N and K fertilizer on weed populations and species in 1973 and found that total week count was affected only by the highest rate of N (672 kg/ha) and that these treatments contained less than half as many weeds as did the N treatments of 0 and 336 kg/ha. They observed that the average number of weed species on treatments receiving the highest N rate was only about 60% as high as those with the two lower N rates. Also, as K rates increased to 168 kg/ha, weed species also increased but decreased as higher K rates (336 and 672 kg/ha) were applied.

Meijden (1974) reported that ragwort (*Senecio jacobaea* L.) populations increased as exchangeable calcium increased. Beard (1973), who recognized the influence of soil fertility on weed populations, stated that certain turf specialists have recommended allowing acidic conditions to exist in turfgrass soils to control weeds. Buchanan et al. (1975) reported that certain weeds such as common chickweed (*Stellaria media* [L.] Cyrillo) redroot pigweed (*Amaranthus retroflexus*), and common dandelion (*Taraxacum officinale*) were sensitive to low soil pH. The Geigy Weed Tables state that henbit (*Lamium amplexicaule* L.) thrives in fertile soils when pH is between 6 and 7 (1968).

Fifteen fertilizer treatments were applied to a Coastal Bermudagrass sod on a Pembroke silt loam at the Main Experiment Station, University of Arkansas, Fayetteville, for the years 1968-1976. Nitrogen rates of 0, 336, and 672 kg/ha and K rates of 0, 84, 168, 336, and 672 kg/ha were applied annually. The experimental design was 3 X 5 factorial arrangement in a randomized complete block. There were four replications. Nitrogen, as NH_4NO_3, was applied in three equal applications after the first three harvests; and K, as KCl, was applied in two equal applications each season. A broadcast application of superphosphate was applied uniformly as needed to supply the phosphorus needs of the plants. In May of 1974, the 2.45 by 6.10 meter plots were split, and finely ground calcitic limestone was applied randomly to one half of each plot at the rates of 2.5, 5.0 and 7.5 MT/ha to the no-N, 336N and 672N treatments, respectively. In May 1976, each of these three N treatments was relimed at the rate of 2.4 and 6 MT/ha, respectively.

The number of weeds and the species were counted 14-15 March 1977, before the bermudagrass emerged, within an area one meter square, randomly selected from the center of each plot. The data collected were subjected to an analysis of variance to determine the nature of the relationship between the soil amendments and total weed population.

The mid-March weed counts showed that henbit (*Lamium amplexicaule* L.) plants accounted for 80% of the total weed population. Other weed species, in decreasing order of abundance, were little barley (*Hordeum pusilium* Nutt.) at 10%, chickweed at 5%, dandelion at 4%, and wild garlic (*Allium vineale* L.), mint (*Labeate* spp) and other weeds at less than 0.5% each.

The average density of all weeds amounted to 8.7/m². Neither the N, the K, nor the N X K interaction affected weed counts. However, both the limestone and the limestone X nitrogen interaction affected the weed population at the 1% level of significance (Table 1). None of the other limestone X fertilizer interactions were significant. The limestone had no effect on the weed population in the no-N treatments, but as N rates increased, weed counts significantly declined in unlimed plots and significantly increased in the limed plots. Visual observation indicated that there was no amendment X weed species interaction; i.e., the ratio of the several weed species remained constant on the variously limed and fertilized treatments. The limed, high-N treatment had almost four times as many weeds as its unlimed counterpart.

Throughout this experiment the soil of the treatments receiving the highest N rate became progressively more acid. By the time these weed counts were made, this surface soil had a pH in the mid to high 3's. This extreme soil acidity may have been the factor that suppressed weed growth. When the weed counts were taken, the experimental site had a striking checkerboard appearance caused by the bright purple flowers of the henbit in the subplots of the N fertilized treatments which had been limed.

While the high N rates on the unlimed treatments affected the weed population in much the same manner as reported by Allured et al. (1974) the effect of N fertilization on weed populations of the limed treatments in 1977 was markedly different. There was no limestone variable in Allured's 1974 experiment.

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

Table 1. Effect of long-term annual nitrogen applications, and 1974 and '76 limestone applications, on early spring weed populations in a Coastal Bermudagrass sod. Weeds/m².

	annual N rates, kg/ha			
	ON	336N	672N	ave
no limestone	7.9c*	5.5d	4.1d	5.8b
limed in 1974 & '76	7.7c	11.5b	15.3a	11.5a

*Values in the average column and in the interaction table not followed by the same letter are significantly different at the 5% level of probability.

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STATUS OF THE ENDANGERED OZARK BIG-EARED BAT (*Plecotus townsendii ingens*) IN ARKANSAS

Three bat taxa endemic to Arkansas are now considered to be endangered (in danger of extinction throughout all or a significant portion of their range). The Indiana bat, *Myotis sodalis*, and the gray bat, *M. grisescens*, are currently on the United States list of endangered species. The Ozark big-eared bat, *Plecotus townsendii ingens*, (along with the Virginia big-eared bat, *P. t. virginianus*) will be added pending final legislation.

The Ozark big-eared bat has been reported in small numbers from only a few caves in northwestern and north central Arkansas, southwestern Missouri, and eastern Oklahoma (U. S. Department of the Interior, Fish and Wildlife Service 1973; Handley 1959; Harvey 1975, 1976, 1978; McDaniel and Gardner 1977; Sealander 1951, 1956; Sealander and Young 1955). The Department of the Interior, Fish and Wildlife Service (1973) estimated the total number surviving to be less than 100 and stated that never more than four individuals had ever been found at one time. That information is incorrect. Sealander (1951) reported collecting 11 individuals from a Washington County, Arkansas, cave in 1951. It was not until 24 years later that a number greater than 11 was reported. Harvey (1975, 1976) reported finding 60 *P. t. ingens* in a western Arkansas cave in February, 1975.

Due to the small number known, relativity little information is available concerning this particular subspecies. However, much is known about the species in other parts of its range, most of which may also apply to *P. t. ingens*. Humphrey and Kunz (1976) published a detailed account concerning the ecology of the southern Great Plains population of *P. townsendii*, considered to be an intergrade of *P. t. pallescens* of the southern Rocky Mountains and *P. t. ingens*. In addition, several authors have reported on the biology of the more abundant western subspecies (Handley 1959; Barbour and Davis 1969; Graham 1966; Dalquest 1974; Pearson et al. 1952; Twente 1955).

In the eastern part of their range *P. townsendii* inhabit caves during both summer and winter, although occasional individuals have been observed in buildings during the summer. In the western part of their range they are often found in buildings. *P. townsendii* hibernate in caves or mines where the temperature is 12° C or less, but generally above freezing. They are usually found clustered in groups of a few to a hundred or more individuals. The species is very intolerant of human disturbance and will sometimes vacate a cave if disturbed (Humphrey 1969; Humphrey and Kunz 1976; Twente 1955; Barbour and Davis 1969).

During the past 5 years numerous caves in northwestern and north central Arkansas were searched in an attempt to locate colonies of Ozark big-eared (as well as other) bats. Name, location, and a brief description of each cave, as well as a record of bat taxa and numbers present, were recorded. Collection of specimens was minimal and usually bats were handled only if necessary for identification purposes. Ecological data such as temperature and humidity of bat microhabitats were recorded. During warmer seasons limited mist netting was conducted in a variety of habitat types.

The colony of 60 *P. t. ingens* reported by Harvey (1975, 1976) from a western Arkansas cave in February, 1975, was not present in the cave when checked during the following winter. However, in early March, 1978, we discovered a cluster of 35 hibernating *P. t. ingens* in another cave in the same general area. Both caves are in Washington County. In November, 1974, we found eight *P. t. ingens* clustered above a guano pile in a Marion County cave. Two skeletons of this bat were found in the guano. An additional Ozark big-eared bat was found in a Marion County mine in February, 1974.

Although numerous other caves and mines in northwestern and north central Arkansas were searched, no additional *P. t. ingens* were discovered. Summer mist netting also failed to result in the capture of Ozark big-eared bats. However, netting was not done in areas near caves and mines from which *P. t. ingens* have been reported.

Our records indicate that *P. t. ingens* prefer relatively cold areas of caves for hibernation. Temperatures where Ozark big-eared bats were found ranged from 4° C to 9° C; humidity was 85-95%. We know nothing concerning summer habitat of this taxon. Quite likely nursery colonies exist somewhere in Ozark caves, but thus far none have been found.

The discovery in the last few years of groups of *P. t. ingens* numbering from eight to 60 individuals indicates that these bats may be present in greater numbers than previously thought. However, the total surviving population may number no more than a few hundred individuals. Their exact status is still relatively unknown. Known colonies will be monitored and attempts will be made to locate additional colonies as well as to identify critical habitat requirements for this taxon. Because no cave regularly inhabited by *P. t. ingens* has been discovered, no critical habitat has as yet been proposed.

Numerous individuals have been involved in our attempts to ascertain the status of the endangered Ozark big-eared bat in Arkansas. Personnel of the Arkansas Game and Fish Commission, Arkansas Department of Parks and Tourism, U. S. Forest Service, and National Park Service have supplied information and otherwise aided in many ways. A number of graduate students and faculty members were involved in field work. We sincerely appreciate the efforts of all those who contributed their time and expertise.

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THE DESIGN AND CONSTRUCTION OF AN INEXPENSIVE ANECHOIC CHAMBER

When any degree of precision is needed in obtaining data on the radiation properties of an acoustical device such as a loudspeaker or musical instrument, measurements are usually taken under free space conditions without the presence of complicating stationary save patterns. Indoor free space measurements require an anechoic room, a room with completely sound absorbing walls. However, a specially designed chamber can be used as a good approximation of an anechoic room.

A portable chamber, as detailed in Figures 1 and 2, can be utilized as an anechoic chamber. In never having any opposite wall face parallel to another, stationary wave patterns will be prevented from establishing themselves. This, combined with the greatly increased surface area due to approximately thirty-five hundred polyurethane wedges, will give the central area of the chamber an anechoic effect. Transmitted noise from outside the chamber is prevented by insulating the chamber with rock wool fiberglass and acoustical ceiling tile.

The walls of the chamber consist of four layers. The outer external layer consisting of three-quarter inch plywood, and, although its primary purpose is that of the skeleton of the chamber, it also serves as the first barrier against external noise. The second layer consist of two inches of rock wool fiberglass insulation, acting as an acoustical absorber of any noise which is able to penetrate the external layer. The third layer, three-quarter inch acoustical ceiling tile, provides three functions: acting as a final barrier to incident noise from the outside, providing a base from which the polyurethane foam can be attached, and absorbing sound generated from the inside of the chamber. The inner layer is a polyurethane foam forming a mosaic of alternating vertical and horizontal wedges projected normally from each surface. Each foam wedge is four square inches at its base and projects four inches toward the central area of the chamber.

The chamber is constructed in two equal parts, allowing for greater mobility, and joined with a latched tongue and groove joint. Steel mesh serves to support equipment placed in the chamber. Quarter-inch holes packed with insulation are placed on either end of the chamber giving access for microphone leads or any other test equipment leads.

While this chamber will not replace a complete full size anechoic room, it will allow for acceptable measurements of acoustical radiation. However, certain limitations are inherent in the dimensions of the chamber. Frequencies lower than 1000 Hz are of sufficient wavelength to cause concern. Any application of the chamber should be restricted to making measurements of radiation above the 1000 Hz limit. Measurements of high frequency resonance response characteristics of string instruments, frequency response of loudspeakers, or frequency characteristics of microphones are but a few of the applications of the chamber.

This chamber was constructed using funds from a grant made possible by the Bendix Corporation through the Society of Physics Students.

(a)

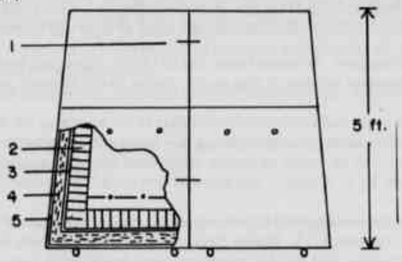

Figure 1(a). End view of chamber showing cut out view of the inside and the locations of: (1) - latches, (2) - polyurethane foam wedges, (3) - ¾ inch acoustical ceiling tile, (4) - 2 inches rock wool insulation, (5) - ¾ inch plywood.

(b)

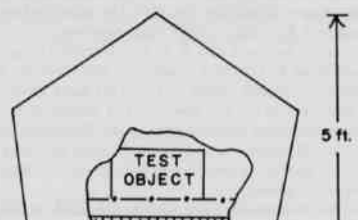

Figure 1(b). Side view of chamber showing placement of a test object supported by wire mesh.

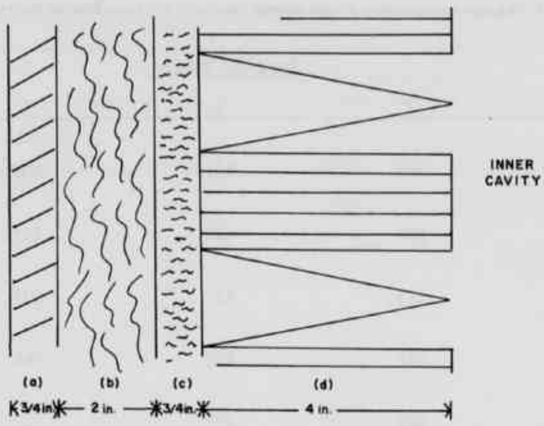

Figure 2. Cross section of the construction of a wall segment. (a)-plywood. (b)-rock wool insulation. (c)-acoustical ceiling tile. (d)-foam wedges.

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AGE AND GROWTH OF CARP FROM BEAVER RESERVOIR, ARKANSAS

The common carp, *Cyprinus carpio* Linnaeus, originally Asiatic, has been introduced into the United States as early as 1876 (Carlander, 1969; Pflieger, 1975). There has been no published information on the growth of carp from Arkansas reservoirs. This paper describes the age and growth of carp from Beaver Reservoir, an impoundment on the White River.

Beaver Reservoir (36°05' to 36°27'N and 93°47' to 94°06'W) located in northwest Arkansas, is a multipurpose impoundment on the White River for flood control and hydroelectric power. Dam construction was completed in 1963, became operational in 1966, and attained the designated surface area of 11,400 ha in 1968.

Of the 127 carp used in this study, 49 were collected in 1968 by rotenone, and 58 and 20 fish in 1969 and 1970, respectively, by 2.5, 3.8, 5.0, and 7.5 cm² gill nets. Upon capture, total length in millimeters and total weight in grams were recorded, and a scale sample was taken from the body at the tip of the pectoral fin above the lateral line. Scale impressions on plastic strips were studied at 40X magnification. Scale radius and distances to each annulus were measured in the anterior field. Age determinations were made by counting the scale annuli.

The length (330 - 668 mm) - weight (454 - 3,500 g) relationship was log W = 3.07 log L - 4.88985. The regression coefficient of 3.07 was not significantly different from 3.0 ($t_{125} = 0.46$), indicating that the weight of carp increased as the cube of length.

The coefficient of condition, K, was calculated for each of the carp from the expression, $K = \frac{W}{L^3} \times 100$. The coefficient for the individual fish ranged from 0.94 to 2.16 with an average value of 1.31. The average coefficient of the Beaver Reservoir carp was similar to that of carp from Smoky Hill River (1.34) but higher than the Cedar Bluff Reservoir carp (0.94) (Stucky and Klassen, 1971). The condition coefficient did not change significantly with fish length ($t_{125} = 0.77$). English (1952), and Stucky and Klassen (1971) found the condition coefficient to decrease with increase in length. Average condition coefficients for the year classes are given in Table 1. Comparison of the year classes 1965 through 1968 resulted in a significant difference in the coefficients ($F_{3,120} = 5.41$), and this was due to high condition coefficient for the 1968 year class.

The total length (L)-scale radius (S) relationship for the Beaver Reservoir carp was L = 81.55 + 0.82S with a correlation coefficient of 0.76. The average calculated lengths at the time of annuli formation are given in Table 2. Comparison of lengths of age-groups I, II, and III revealed no difference at the 0.01 level between the year classes 1965 through 1968. Therefore, the postimpoundment growth was the same for all the year classes.

Year Class	Average K_{TL}	Number of Fish
1963	1.15	1
1964	1.30	2
1965	1.31	15
1966	1.28	54
1967	1.29	41
1968	1.48	14

Table 1. Average coefficient of condition (K_{TL}) for year classes 1963 through 1968.

Table 2. The average calculated total lengths (mm) of carp from Beaver Reservoir.

Year Class	Annulus Number 1	2	3	4	5
1963	229	364	451	508	578
1964	287	389	434	497	529
1965	265	363	421	537	-
1966	282	387	455	565	-
1967	283	387	465	-	-
1968	299	416	-	-	-
Weighted Average	282	384	444	527	554
Number of Fish	127	123	45	8	2

We wish to thank Mr. Louis E. Vogele, South Central Reservoir Investigations for reviewing the manuscript.

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ADDITIONS TO THE FISH FAUNA OF PINEY CREEK, IZARD COUNTY, ARKANSAS

Notice is given of the addition of three species to the known ichthyofauna of Piney Creek, Izard County, Arkansas. Matthews and Harp (Proc. Ark. Acad. Sci., 28:39-43, 1974) reported a total of 44 species from the watershed. On 17 October 1975, we collected one small adult speciment of *Salmo gairdneri* (Rainbow trout) from a swift pool on Piney Creek in SE¼, Sec 5, T 16 N, R 10 W (Station P-1 of Matthews and Harp). This locality is approximately 1.2 km upstream from the confluence of Piney Creek with White River, from which the specimen doubtlessly migrated. Piney Creek is too warm in the summer to permit survival of salmonids. The next day we collected two specimens each of *Notropis greenei* (Wedgespot shiner) and *Labidesthes sicculus* (Brook silversides) approximately 0.3 km upstream from the previous location. The creek at this locality consisted of alternating gravel-rubble riffles and shallow pools. The specimens of *S. gairdneri*, *N. greenei*, and *L. sicculus* are deposited as collections number 4894, 4896, and 4897, respectively, in the Arkansas State University Museum of Zoology.

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AN UNUSUAL ACCUMULATION OF BAT REMAINS FROM AN OZARK CAVE

A total of at least 10 species representing six genera of vespertilionid bats has been identified from 1445 skulls collected from the floor of a limestone cave in the Sylamore Ranger District, Ozark National Forest, Arkansas (Table 1). This accumulation of skeletal material was found in a passageway divided into two distinct zones on the basis of constant or fluctuating temperatures. Fluctuating temperatures were encountered at the anterior end of the passageway and were obviously related to ambient temperatures at the nearby entrance; constant temperatures were recorded throughout the remainder of the passageway. The passageway was dry and ranged from one to two meters in height. Bat remains varied from skulls coated with calcite (calcium carbonate) crystals to decomposing carcasses and included several mummified specimens. Of the 10 species identified, four are considered tree bats and are recognized to rarely enter caves; the remaining species typically utilize caves as habitat during some portion of their annual activity cycles.

Table 1. Species, number, and temperature zone of bats collected in an Ozark Cave.

Species	No. Collected	Temp. Zone
Pipistrellus subflavus	617	Constant
Myotis grisenscens	369	Cons. & Var.
Myotis lucifugus	100+	Cons. & Var.
Myotis sodalis	2+	Constant
Myotis keenii	1+	Constant
Myotis spp.	197	Cons. & Var.
Eptesicus fuscus	3	Variable
Lasiurus borealis	140	Constant
Lasiurus cinereus	6	Constant
Nycticeius humeralis	9	Constant
Lasionycteris noctivagans	1	Constant

Myers (1960, *Lasiurus* from Missouri caves. J. Mamm. 41:114-117) noted that although cave bats such as *Myotis, Eptesicus,* and *Pipistrellus* commonly used caves in which lasiurine (tree) bats were found, rarely were any of these true cave bats found dead in the caves. Interestingly, the opposite is true in this observations, since 89% of the remains were of cave dwelling species.

Of additional importance was the recovery of two species of tree bats rarely encountered in caves. Nine specimens of the evening bat, *Nycticeius humeralis,* were recovered from the constant temperature zone of the cave. These specimens represent the largest aggregation of evening bats reported from a limestone cave in Arkansas. On only two other occasions have evening bats been reported from caves of Missouri and Arkansas (Easterla, D. A. 1965. A nursery colony of evening bats in southern Missouri. J. Mamm. 46:498; McDaniel, V. R. and J. E. Gardner. 1977. Cave fauna of Arkansas: vertebrate taxa. Proc. Ark. Acad. Sci. 31:68-71).

One specimen of the silver-haired bat, *Lasionycteris noctivagans,* was removed from the constant temperature zone and represents the only specimen of this bat taken from a limestone cave in Arkansas. According to Barbour and Davis (1969. Bats of America. Univ. Kentucky Press, Lexington. p. 107), the silver-haired bat rarely enters caves, and there are published records of only six specimens found in caves (Krutzsch, P. H. 1966. Remarks on the silver-haired and Leib's bats in eastern United States. J. Mamm. 47:121).

Skeletons of two other tree bats, *Lasiurus borealis* and *L. cinereus,* were numerous, but their presence in caves has been reported earlier (Beer, J. R. 1954. A record of the hoary bat from a cave. J. Mamm. 35:116; Quay, W. B. and J. S. Miller. 1955. Occurrence of the red bat, *Lasiurus borealis,* in caves. J. Mamm. 36:454-455).

The presence of such large numbers of bat remains in a cave is intriguing, particularly in light of the abundance of cave bat remains. While tree bats might conceivably enter the cave environment, go into torpor, and in the absence of normal epigean stimuli, fail to ever come out of torpor, cave bats obviously should not suffer such a fate. Additionally, the abundant cave bat remains and the relative proximity of the cave entrance discount the possibility of the tree bats simply becoming lost in an unfamiliar area. Although we cannot readily explain the presence of the tree bats in this cave, our studies on swarming activities at the mouth of this cave reveal an abundance of these species at the cave mouth. The large accumulation of cave bat remains appears to be related to a peculiarity of the entrance of this cave. The entrance is a sinkhole that often floods during spring rains. It appears that many years the entrance remains flooded for extended periods, not allowing bats to exit. Apparently these periods of prolonged flooding have coincided with normal spring emergence and the bats, with energy stores critically depleted, were unable to survive without access to food during this period.

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GEOCHEMISTRY OF A CARBONATITE IN MONTGOMERY COUNTY, ARKANSAS

In a previous paper (Wagner and Steele, 1977) the chemical compositions of carbonatites in Conway and Perry Counties of Arkansas were compared. No large differences were found except those due to varying amounts of weathering. This paper reports on a lone carbonatite in Montgomery County (sec. 11,T4S,R23W) that has not been mentioned in earlier publications on igneous rocks of Arkansas (Croneis and Billings, 1930; Stone and Sterling, 1964). It is located 92 km southwest of the nearest Perry County carbonatite, 53 km west of the Magnet Cove igneous complex and 50 km northeast of the Murfreesboro peridotite. Table 1 compares the composition of the Montgomery County carbonatite to its nearest carbonatite neighbors. Its chemical composition is very near to that of the Perry County carbonatite. Notable exceptions are its lower Na, K and Sr and higher Ni contents. Major elements are similar in percentage to the average for the Perry and Conway County carbonatites. There are fewer xenoliths in the Montgomery County carbonatite.

Only a few square meters of a highly weathered portion of the Montgomery County carbonatite are exposed. Soil and stream sediment samples from a limited area around this weathered exposure were analyzed in an effort to determine geochemical indicators of the carbonatite. Figure 1 shows the location of the sampling sites and the weathered intrusive area. Table 2 lists the analyses.

The carbonatite appears to be confined to a southeast trending ridge about 15 meters high and 110 meters across. Samples PW-10, 12 and 13 are from weathered exposures of the carbonatite on the western slope of the ridge. PW-14 is from altered wall rock on the eastern slope and PW-21 is a B-horizon soil sample from a mid point at the top of the ridge. All other soil samples are labeled PW and are from the top of B-horizon, except PW-15 which is from the A-horizon. Stream sediment samples are labeled Ou in Figure 1. Both soil and sediment samples were sieved on a 95 mesh nylon screen and the minus 95 mesh fraction dissolved in a combination of hydrofluoric acid and aqua regia for the analyses reported in Table 2. Analyses were by atomic absorption using a model 303 Perkin Elmer Spectrophotometer and the recommended procedures (Anonymous, 1973).

Soil samples within the drainage area of the carbonatite generally have the higher metal values, particularly Cu, Zn, Mn and Ba. This is true also of the sediment samples Ou-40 and Ou-35, from the stream which directly drains the carbonatite area. These metals - Cu, Zn, Mn and Ba - are thus the best indicators of the carbonatite.

Table 1. Chemical Analyses of Montgomery County Carbonatite Compared to a Perry County and Magnet Cove Carbonatite (data in wt. %)

Carbonatite	Ca	Mg	Fe	Ti	Mn	Na	K	
Perry Co.[1]	24.4	2.58	6.92	0.64	0.478	1.07	2.23	
Montgomery Co.	20.8	2.47	5.74	0.76	0.286	0.107	0.261	
Magnet Cove[2]	38.1	0.63	0.54	0.06	0.500	0.00	0.13	
	Ba	Sr	Zn	Co	Ni	Cu	V	Li
Perry Co.[1]	0.136	0.3884	0.0190	0.0037	0.0010	0.0012	0.0147	0.0011
Mongtomery Co.	0.100	0.1020	0.0080	0.0060	0.0460	0.0020	0.0220	0.0017
Magnet Cove[2]	0.100	-	-	0.00	0.00	0.0010	0.0200	-

[1] analysis of Brazil Branch carbonatite (Wagner and Steele, 1977)

[2] analysis of sample L-304, Erickson and Blade (1963)

Figure 1. Location map for soil samples (PW) and stream sediment (Ou) samples taken around intrusive area of the Montgomery County carbonatite.

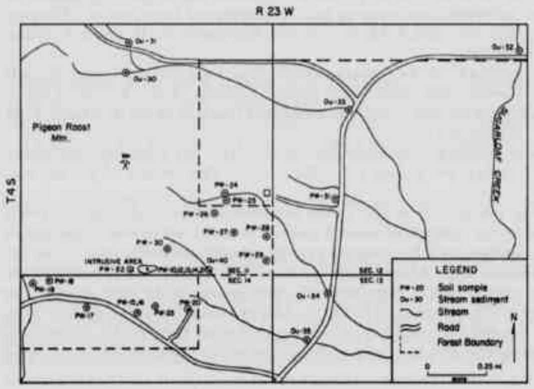

Table 2. Soil (PW) and Stream Sediment (Ou) Analyses Near Montgomery County Carbonatite* (data in ppm)

Sample	V	Co	Ni	Cu	Zn	Mn	Ba	Li	Sr
PW-10	615	263	490	180	313	12,040	1061	35	1208
PW-12	732	51	224	138	339	376	1378	18	949
PW-13	772	307	330	709	407	13,500	893	60	696
PW-14	209	123	606	66	259	36,700	407	59	117
PW-15	96	16	29	53	64	187	105	26	40
PW-16	57	7	13	29	46	419	95	14	29
PW-17	57	17	20	46	43	73	125	27	52
PW-18	57	17	20	32	52	114	125	20	36
PW-19	135	9	14	32	34	92	130	21	38
PW-20	74	20	20	40	70	281	115	25	36
PW-21	135	19	36	43	66	260	161	24	83
PW-22	96	30	40	39	87	1,116	234	29	49
PW-23	135	20	34	56	84	187	146	30	30
PW-24	74	12	30	41	58	73	161	25	15
PW-25	74	20	31	56	87	144	150	29	26
PW-26	113	13	14	39	37	92	269	19	29
PW-27	96	20	27	95	96	135	156	25	26
PW-28	96	16	24	38	54	83	781	39	44
PW-29	74	6	16	26	34	175	166	15	26
PW-30	113	23	74	65	131	3,649	747	36	60
PW-31	74	9	16	36	54	251	1037	22	35
Average PW**	91	16	27	45	64	431	277	25	38
Ou-30	153	44	50	47	90	1,431	1173	48	60
Ou-31	96	72	40	18	54	624	111	34	36
Ou-32	39	37	52	22	70	376	238	36	39
Ou-33	17	22	26	18	43	376	90	13	23
Ou-34	17	15	21	24	40	291	136	14	26
Ou-35	39	29	33	30	64	570	264	21	36
Ou-40	74	46	255	104	315	7578	623	-	45

* Analyses are for minus 95 mesh fractions which were dissolved in hydrofluoric acid followed by aqua regia and analyzed by atomic absorption. Ou-40 had aqua regia only.

** PW-10, 12, 13, 14 not included in average.

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PUBLICATION POLICIES AND SUGGESTIONS FOR AUTHORS

The PROCEEDINGS OF THE ARKANSAS ACADEMY OF SCIENCE appears annually. At least one of the authors of a paper submitted for publication in the PROCEEDINGS must be a member of the Arkansas Academy of Science.

Each paper should contain results of original research, embody sound principles of scientific investigation, and present data in a concise yet clear manner. The COUNCIL OF BIOLOGY EDITORS STYLE MANUAL, published by the American Institute of Biological Sciences, is a convenient and widely consulted guide for scientific writers. Authors should strive for directness and lucidity, achieved by use of the active voice. Special attention should be given to consistency in tense, unambiguous reference of pronouns, and logically placed modifiers.

Preparation of Manuscript

It is strongly recommended that before submitting a paper, the author ask qualified people to appraise it. The author should submit two copies of the manuscript, tables, and figures. Manuscripts must be double-spaced (preferably typed with a carbon ribboned typewriter) on 8½ x 11 inch bond paper with at least one inch margins on all sides. Do not hyphenate words on the right-hand margin. The second copy may be xeroxed.

An abstract summarizing in concrete terms the methods, findings and implications discussed in the body of the paper must accompany a feature article. The abstract should be completely self-explanatory.

A feature article comprises approximately five or more typewritten pages. A PROCEEDINGS printed page is equal to approximately three and one-half typewritten pages and the author is assessed a page charge for those papers exceeding two printed pages. A separate title page, including the title in capital letters, the authors names and addresses should be included with the manuscript. Feature articles are often divided into the following sections: abstract, introduction, materials and methods, results, discussion, acknowledgments, and literature cited. These sections should be centered and capitalized. Subheadings should begin at the left-hand margin, but more than one subheading should be avoided.

A general note is usually one to three typewritten pages and rarely utilizes subheadings. A note should have the title (capitalized) at the top of the first page with the body of the paper following. Abstracts are not used for general notes. The authors name and address should appear at the end of the manuscript. For other information concerning general note format consult Vol. 31 of the PROCEEDINGS.

Abbreviations: Use of abbreviations and symbols can be ascertained by inspection of recent issues of the PROCEEDINGS. Suggestions for uniformity include the use of numerals before units of measurement (5 millimeters), but nine animals (10 or numbers above, such as 13 animals). Abbreviations must be defined the first time they are used. The metric system of measurements and weights must be employed.

The literature cited section should include six or more references; entries should take the following form:

DAVIS, D.H.S. 1933. Rhythmic activity in the short-tailed vole, *Microtus*. J. Anim. Eco. 2:232-238.

HUDSON, J. W. and J. A. RUMMELL. 1966. ....

FLEMING, T. H. 1969. Population ecology of three species of Neotropical rodents. Unpublished Ph.D. dissertation, Univ. Michigan, Ann Arbor, 231 pp.

JONES, I. C. 1957. The adrenal cortex. Cambridge Univ. Press, London, 316 pp.

WRIGHT, P. L. 1966. Observations on the reproductive cycle of the American badger *(Taxidea taxus)*. Pp. 27-45, *In* Comparative biology of reproduction in mammals (I.W. Rowlands, ed.) Academic Press, London, xxi + 559 pp.

If fewer than six references are cited they should be inserted in text and take these forms: Jones, The adrenal cortex, p. 210, 1957); (Davis, J. Anim. Ecol., 2:232-238, 1933).

Tables and illustrations: Tables and figures (line drawings, graphs, or black and white photographs) should not repeat data contained in the text. The author must provide numbers and short legends for illustrations and tables and place reference to each of them in the text. Legends for figures should be typed on a separate piece of paper at the end of the manuscript. Do not run tables in the text. Illustrations must be of sufficient size and clarity to permit reduction to standard page size; ordinarily they should be no larger than twice the size of intended reduction and whenever possible no larger than a manuscript page for ease of handling. Photographs must be printed on glossy paper; sharp focus and high contrast are essential for good reproduction. Figures and labeling must be of professional quality. Notations identifying author, figure number, and top of print must be made on the back of each illustration. All illustrations must be submitted in duplicate. Tables should be typed with a carbon-ribboned typewriter and in the exact format that the author wishes them to appear in the text. Tables will be printed using the offset process and thus must be of professional quality when submitted. Note preferred placement of figures and tables in the margins of the manuscript.

Procedure

It is the policy of the Arkansas Academy of Science that only papers presented at the annual meeting are eligible for publication and that the manuscript is due at the time of presentation. In accordance with this policy, manuscripts submitted for publication should be given to the section chairman as the paper is being presented. Correspondence after this time should be directed to Gary A. Heidt, Editor, Dept. of Biology, University of Arkansas at Little Rock, Little Rock, Arkansas 72204.

Evaluation of a paper submitted to the PROCEEDINGS begins with a critical reading by the editor. The paper is then submitted to referees for checking of scientific content, originality, and clarity of presentation. Attention to the preceding paragraphs will greatly speed up this process. Judgments as to the acceptability of the paper and suggestions for strengthening it are sent to the author. If the paper is tentatively accepted the author will rework it, where necessary, and return two copies of the revised manuscript together with the original to the Editor. Usually a time limit for this revision will be requested. If the time limit is not met, the paper may be considered to be withdrawn by the author and rejected for publication. All final decisions concerning the acceptance or rejection of a manuscript are made by the Editor.

When a copy of the proof, original manuscript, and reprint order blanks reach the author, they should be carefully read for errors and omissions. The author should mark corrections on the proof and return both the proof and manuscript to the Editor within 48 hours or the proof will be judged correct. Printing charges accruing from excessive additions to or changes in the proofs must be assumed by the author. Reprint orders are placed with the printer, not the editor. Page charges, where applicable, and excessive printing charges will be billed to the author by the Academy of Science.

ABSTRACT COVERAGE

Each issue of the Proceedings is sent to several abstracting and review services. The following is a partial list of this coverage:

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Chemical Abstracts
Mathematical Reviews
Recent Literature of the Journal of Mammalogy
Science Citation Index
Sport Fishery Abstracts
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