

1971

Proceedings of the Arkansas Academy of Science - Volume 25 1971

Academy Editors

Follow this and additional works at: <https://scholarworks.uark.edu/jaas>

Recommended Citation

Editors, Academy (1971) "Proceedings of the Arkansas Academy of Science - Volume 25 1971," *Journal of the Arkansas Academy of Science*: Vol. 25 , Article 1.

Available at: <https://scholarworks.uark.edu/jaas/vol25/iss1/1>

This article is available for use under the Creative Commons license: Attribution-NoDerivatives 4.0 International (CC BY-ND 4.0). Users are able to read, download, copy, print, distribute, search, link to the full texts of these articles, or use them for any other lawful purpose, without asking prior permission from the publisher or the author.

This Entire Issue is brought to you for free and open access by ScholarWorks@UARK. It has been accepted for inclusion in Journal of the Arkansas Academy of Science by an authorized editor of ScholarWorks@UARK. For more information, please contact scholar@uark.edu, cmiddle@uark.edu.

78
1.25
op. 2

Journal of the Arkansas Academy of Science, Vol. 25 [1971], Art. 1
Proceedings of the
UNIV. OF ARK. LIBRARY
ARKANSAS ACADEMY OF SCIENCE

Coden: ^S
AKASO



Sphingidae of Northeast Arkansas — Page 56

Volume XXV
1971

ARKANSAS ACADEMY OF SCIENCE
BOX 1709 UNIVERSITY OF ARKANSAS
FAYETTEVILLE, ARKANSAS 72701

SPECIAL 4th. CLASS
BOOK RATE

EDITOR Lester C. Howick
Department of Chemistry, University of Arkansas
Fayetteville, Arkansas 72701

EDITORIAL BOARD

James L. Dale	Jewel E. Moore
Carl E. Hoffman	Joe F. Nix
G. T. Johnson	Roy C. Rom
Max C. Milam	J. W. Sears

GUIDELINES FOR AUTHORS

Eligibility for publication in the Proceedings is limited to those papers which have been presented at the annual meeting by one of the authors. At least one of the authors must be a member of the Academy, except that the Editorial Board is authorized to accept articles for publication from invited speakers. Manuscripts are to be presented to the section chairmen at the time of the reading of the paper. The Editorial Board reserves the right to edit, shorten, or reject any papers submitted to it. In general, submitted papers will be reviewed by persons competent in the area of study.

Manuscripts should be typewritten, double spaced throughout, with the format followed being that of a commonly used journal in the area of study. Illustrations may be used but special care should be exercised to insure that drawings and photographs are of the highest quality. Such illustrations should be properly proportioned to fit the Proceedings page and lettering should be large enough to be legible upon size reduction.

Manuscripts will normally be limited to three (Proceedings) pages with pages in excess of this being charged to the author at cost. Authors may be expected to bear charges arising from exceptional typesetting or illustration.

The Editor will inform authors of the arrangement for ordering reprints and of the cost of reprints at the time that page proofs are prepared.

BUSINESS AND SUBSCRIPTION INFORMATION

Remittances and orders for subscriptions and for single copies and changes of address should be sent to Dr. William C. Guest, Secretary, Arkansas Academy of Science, Box 1709, University of Arkansas, Fayetteville 72701.

Subscription rates for 1971 are \$5.00 per copy with members receiving one free copy with their full membership of \$8.00 or their sustaining membership of \$10.00. Institutional members and industrial members also receive one free copy. Copies of back issues are available. The Secretary should be contacted for prices and for special complete back issue discounts available to libraries.

ABSTRACT COVERAGE

Each issue of the Proceedings is sent to several abstracting and review services. The following is a partial list of this coverage:

- Abstracts in Anthropology
- Abstracts of North American Geology
- Biological Abstracts
- Biological and Medical Abstracts
- Chemical Abstracts
- Chemical Titles
- Mathematical Reviews
- Science Citation Index
- Sport Fishery Abstracts
- Wildlife Review
- Zoological Record
- Review Journals of the Commonwealth Agricultural Bureaux

Printed by: Southwest Printing Co., Fayetteville, Arkansas

Robert Kirkwood
President

William C. Guest
Secretary

John P. Jones
Treasurer

George E. Templeton
President-Elect

Arkansas Academy of Science, Box 1709, University of Arkansas
Fayetteville, Arkansas

UNIVERSITY LIBRARY
UNIVERSITY OF ARKANSAS
FAYETTEVILLE, ARKANSAS 72701

ARKANSAS ACADEMY OF SCIENCE

Volume XXV

Proceedings

1971

Secretary's Report

The 55th Annual Meeting of the Arkansas Academy of Science was held at Harding College, Searcy, April 16 and 17, 1971, with Professor Robert Kirkwood, State College of Arkansas, President of the Academy, presiding.

At the business meeting, Dr. J. P. Jones, Treasurer, circulated the Financial Statement which is presented below.

Financial Statement

Arkansas Academy of Science

April 1, 1971

Balance on hand April 1, 1970	\$1083.46
Reserve Fund	1423.64
Total Assets	2507.10

Receipts April 1, 1970 - March 31, 1971

1. Membership dues	1083.43
2. Institutional Memberships	600.00
3. Industrial Memberships	50.00
4. Sales of Proceedings	495.00
5. ABCD Conference Contribution U of A	300.00
Total Receipts	2,528.43

Disbursements April 1, 1970 - March 31, 1971

1. M. L. Lawson — Expenses	37.70
2. Collegiate Acad. of Science—Expenses	48.50
3. Gregory Ferguson—Talent Search Winner	20.00
4. Karen Adcock—Talent Search Winner	16.95
5. U. of A.—Office supplies	8.40
6. Elizabeth Bayson—Annual banquet decorations	5.00
7. William Guest—Postage	32.00
8. Holiday Inn—Executive meeting	34.05
9. Robert Kirkwood—Postage	8.50
10. U. of A.—Xerox copies	7.50
11. ABCD Conference Expenses	257.50
12. AAAS—Annual Contribution	6.00
13. E. E. Hudson—Junior Academy	200.00
14. U. of A.—Office supplies	13.03
15. Verona Tice—Jr. Acad. research grant	75.00
16. Pam Miller—Jr. Acad. research grant	25.00
17. U. of A.—rebate of ABCD funds	42.50
18. U. of A.—Office supplies	5.10
19. Southwest Printing—Envelopes	10.10
20. Ark. Alumni Assoc.—Mailing costs	12.48
21. U. of A.—Office supplies	5.10
Total disbursements	870.41

Summary

Original Balance	1083.46
Receipts	2528.43
Total Receipts	3611.89
Less Disbursements	870.41
Balance	2741.48
Reserve Fund	1423.64
Interest on Reserve Fund	79.08
Total Reserve	1502.72
Total Assets April 1, 1971	4244.20

The Editor, Dr. L. C. Howick, described the changes which have been made in volume 24, 1970, of the Proceedings, and he indicated that volume 24 would be ready for distribution to the membership in early summer.

Representatives of the following Academy sponsored activities presented reports. These reports are a part of the secretary's permanent record and are summarized in the Minutes of the 55th Annual Business Meeting.

Collegiate Academy of Science — Dr. Joe Nix

Junior Academy of Science — Dr. E. E. Hudson

Junior Science and Humanities Symposium — Dr. Eugene Wittlake

Arkansas Biology Curriculum Development Conference — Dr. W. L. Evans

Science Talent Search — Dr. Leo Paulissen

State Science Fair — Mr. Joe Sanders

There was a lengthy discussion of the State Science Fair at both business meetings. The State Science Fair is an independent organization which has been closely associated with the Academy for many years. The Fair was not held this year, and a number of Academy members felt that without the State Fair the regional fairs might suffer. Professor Sanders reported on his efforts to revive the State Science Fair and announced that Mr. Philip Easley had agreed to serve as State Director and that Dr. W. E. Sohl had offered his services to assist in obtaining the necessary financial support. Current plans are to have the State Fair at some central location. The Academy will not be involved as a sponsor, but it is hoped that the members will give this independent effort their strong support.

Secretary's Report and Financial Statement

Dr. Lowell Bailey, who has been associated with the State Science Fair for many years, was presented a plaque by student and faculty participants in appreciation of his leadership and untiring efforts on behalf of the Science Fair.

Dr. W. E. Sohl reported on the status of the State Science and Technology Council. The Council which was appointed by the Governor in 1970 no longer exists. The 1971 legislature established the Science and Technology Council under House Bill 650 and the Governor will appoint a new Council. The Secretary was directed to include a copy of H. B. 650 as a part of the official minutes and to distribute a copy to each member with the minutes.

The Academy elected Dr. Eugene Wittlake, Arkansas State University, as President-Elect. Dr. J. P. Jones, Treasurer, was nominated for one additional year as Treasurer and agreed to serve.

Following a brief discussion it was recommended that for future meetings the Call for Papers be made on a form similar to that currently used by the American Chemical Society.

President Kirkwood announced that the Spring, 1972, meeting would be held at The University of Arkansas, Fayetteville, April 7 and 8, 1972.

Respectfully Submitted

William C. Guest

A Half Century of the Arkansas Academy of Science

NO.	DATE	PLACE	HOST	PRESIDENT	VICE PRESIDENT or PRESIDENT ELECT
1.	1/11/'17	Little Rock U. A. Med. Sch.		Brookover, Chas.	Smith, Morgan
	Interval for World War I.				
16.	11/9/'32	Little Rock		Moore, Dwight M.	Swartz, Delbert
17.	Apr. '33	Little Rock, Lafayette Hotel		Moore, Dwight M.	Allen, Chas. F.
18.	'34	Conway, A.S.T.C.		Haas, Flora	Hyman, H. H.
19.	'35	Arkadelphia, H.S.T.C.		Hyman, H. H.	Munn, W. C.
20.	'36	Monticello Ark. A. & M.		Ham, L. B.	Horton, P. G.
21.	'37	Fayetteville, U. of A.		Munn, W. C.	Smith, T. L.
22.	'38	Clarksville, Col. of Ozarks		McHenry, M. J.	Wills, I. A.
23.	'39	Conway, Hendrix		Smith, T. L.	Leach, L. O.
24.	'40	Fayetteville, U. of A.		Horton, P. G.	Demaree, Delzie
25.	4/25 '41	Arkadelphia, H.S.T.C.		Wills, I. A.	Roberts, L. B.
26.	5/1,2 '42	Monticello, Ark. A. & M.		Wills, I. A.	Roberts, L. B.
27.	5/1/ '43	Little Rock U. A. Med. Sch.		Roberts, L. B.	Abbott, C. E.
28.	5/6 '44	Little Rock U. A. Med. Sch.		Roberts, L. B.	Dennison, Maggie
29.	4/28/ '45	Little Rock U. A. Med. Sch.		Banks, Jeff	Beach, I. T.
30.	'46	Little Rock Junior College		Winburn, H. L.	Erwin, W. G.
31.	5/2,3 '47	Little Rock U. A. Med. Sch.		Winburn, H. L.	Mundie, J. R.
32.	5/7,8 '48	Fayetteville, U. of A.		Provine, E. A.	Bogan, H. L.
33.	5/6,7 '49	Little Rock, U. A. Med. Sch.		Robinette, G. V.	Armstrong, M. Ruth
34.	5/5,6 '50	Petit Jean State Park		Totter, R. H.	Austin, R. H.
35.	4/27,8 '51	Fayetteville, U. of A.		Austin, R. H.	Foxhall, H. B.
36.	4/25,6 '52	Jonesboro, Ark. State Col.		Spessard, E. A.	Swartz, Delbert
37.	4/27,8 '53	Clarksville, Col. Ozarks		Swartz, Delbert	Harvalik, Z. V.
38.	4/23,4 '54	Fayetteville, U. of A.		Harvalik, Z. V.	Armstrong, M. Ruth
39.	4/22,3 '55	Searcy, Harding Col.		Armstrong, M. Ruth	Nedrow, W. W.
40.	4/20,1 '56	Arkadelphia, Ouachita Bap. Col.		Nedrow, W. W.	Sears, Jack W.
41.	4/26,7 '57	Fayetteville, U. of A.		Sears, Jack W.	Mundie, J. R.
42.	4/25,6 '58	Little Rock, U. A. Med. Sch.		Mundie, J. R.	Hoffman, C. E.
43.	3/20,1 '59	Siloam Springs John Brown University		Hoffman, C. E.	Buffaloe, N. D.
44.	4/1,2 '60	Russellville, Ark. Tech.		Buffaloe, N. D.	Bogan, H. L.
45.	4/14,5 '61	Fayetteville, U. of A.		Bogan, H. L.	McEver, Trumann
46.	4/13,4 '62	Searcy, Harding College		McEver, Trumann	Shideler, Robert
47.	4/5,6 '63	Conway, Hendrix College		Shideler, Robert	Moore, D. M.
48.	4/17,8 '64	Conway, A.S.T.C.		Moore, D. M.	Bailey, L. F.
49.	4/2,3 '65	Fayetteville, U. of A.		Bailey, L. F.	Fribourg, Jas. H.
50.	4/1,2 '66	Little Rock, L. R. College		Fribourg, Jas. H.	Moore, Howard
51.	4/7,8 '67	Jonesboro Ark. State U.		Moore, Howard	Chapman, John J.
52.	4/5,6 '68	Arkadelphia, Ouachita & H.S.T.C.		Chapman, John J.	Fry, Arthur
53.	4/11,2 '69	Fayetteville, U. of A.		Fry, Arthur	Lawson, M. L.
54.	4/17,8 '70	Russellville, Ark. Tech.		Lawson, M. L.	Kirkwood, R. T.
55.	4/16,7 '71	Searcy, Harding College		Kirkwood, R. T.	Templeton, Geo. E.
56.	4/7,8 '72	Fayetteville, U. of A.		Templeton, Geo. E.	Wittlake, E. B.

1. f indicates format change.

2. c indicates color change.

Secretary	Treasurer	Editor	Proceedings	Papers	Pages	Historian
Gann, Dewel Interval	Heagney, H. A.	(Permanent Secy. Troy Lewis.)				
Ham, L. B.	Schwardt, H. H.					
Turner, L. M.	Schwardt, H. H.					
Turner, L. M.	Dellinger, S. C.	Swartz, D.				
Turner, L. M.	Horsfall, W. R.	Dennison, Maggie				
Turner, L. M.	Horsfall, W. R.	Singleton, J.				
Turner, L. M.	Horsfall, W. R.	Wills, I. A.				
Ham, L. B.	Holcomb, D. Y.	Horton, P. G.				
Ham, L. B.	Holcomb, D. Y.	Armstrong, M. R.				
Ham, L. B.	Horsfall, W. R.	Moore, D. M.	Vol. I	17	78	
Ham, L. B.	Horsfall, W. R.	Moore, D. M.				
Ham, L. B.	Horsfall, W. R.	Moore, D. M.				
Ham, L. B.	Smith, T. L.	Moore, D. M.				
Ham, L. B.	Smith, T. L.	Moore, D. M.				
Ham, L. B.	Smith, T. L.	Moore, D. M.				
Ham, L. B.	Smith, T. L.	Moore, D. M.				
Ham, L. B.	Smith, T. L.	Moore, D. M.	II	14	70	
Ham, L. B.	Smith, T. L.	Moore, D. M.				
Grigorieff, W. W.	Smith, T. L.	Moore, D. M.				
Grigorieff, W. W.	Smith, T. L.	Moore, D. M.	III	12	98	
Grigorieff, W. W.	Smith, T. L.	Moore, D. M.	IV f ¹	23	200	
Grigorieff, W. W.	Smith, T. L.	Hoffman, C. E.	V	25	162	
Smothers W. J.	Smothers, W. J.	Hoffman, C. E.	VI	18	89	
Smothers W. J.	Smothers, W. J.	Hoffman, C. E.				
Smothers W. J.	Smothers, W. J.	Hoffman, C. E.	VII & VIII f ¹	21	221	
Bailey, Lowell F.	Bailey, Lowell F.	Hoffman, C. E.	IX c ³	12	151	
Bailey, Lowell F.	Bailey, Lowell F.	Hoffman, C. E.	X	8	59	
Bailey, Lowell F.	Bailey, Lowell F.	Noyce, Wm. K.	XI, XII	8, 8	70, 78	
Bailey, Lowell F.	Bailey, Lowell F.	Noyce, Wm. K.	XIII	9	107	
Evans, W. L.	Fairchild, R. J.	Novce, Wm. K.	XIV	7	62	
Corey, R. R.	Fairchild, R. J.	Noyce, Wm. K.	XV	7	88	D. M. Moore
Corey, R. R.	Dale, E. E.	Dale, Jas. L.	XVI c ³	8	57	D. M. Moore
Corey, R. R.	Dale, E. E.	Dale, Jas. L.	XVII	11	89	D. M. Moore
Corey, R. R.	Dale, E. E.	Dale, Jas. L.	XVIII	14	93	D. M. Moore
Templeton, G. E.	Dale, E. E.	Dale, Jas. L.	IXX	18	112	D. M. Moore
Templeton, G. E.	Hoff, V. J.	Dale, Jas. L.	XX	17	124	D. M. Moore
Templeton, G. E.	Jones, J. P.	Howick, L. C.	XXI	15	102	D. M. Moore
Templeton, G. E.	Jones, J. P.	Howick, L. C.	XXII	16	108	D. M. Moore
Templeton, G. E.	Jones, J. P.	Howick, L. C.	XXIII	30	212	D. M. Moore
Guest, Wm. C	Jones, J. P.	Howick, L. C.	XXIV f ¹	26	91	D. M. Moore
Guest, Wm. C	Jones, J. P.	Howick, L. C.	XXV	16	84	

Complied and submitted by:
 Dwight M. Moore
 Historian

Program

PROGRAM

Arkansas Academy of Science

Fifty-fifth Annual Meeting
HARDING COLLEGE
Searcy, Arkansas

Friday, April 16, 1971

SENIOR, COLLEGIATE, JUNIOR ACADEMY—Registration

COLLEGIATE ACADEMY — Executive Committee

SENIOR ACADEMY — Executive Committee

SENIOR ACADEMY — Business Meeting

COLLEGIATE ACADEMY — Luncheon

COLLEGIATE ACADEMY—Speaker:

"Fallout from Chinese Nuclear Detonations",
DR. P. C. KURODA, University of Arkansas

JUNIOR ACADEMY — Business Meeting

COLLEGIATE ACADEMY SYMPOSIUM —
"Environmental Responsibilities"

SCIENCE EDUCATION SECTION

SCIENCE TALENT SEARCH

JUNIOR ACADEMY—Section Meetings

SENIOR ACADEMY — Section Meetings

JUNIOR ACADEMY — Awards Presentation

COLLEGIATE ACADEMY — Business Meeting

SENIOR ACADEMY DINNER

SENIOR ACADEMY SPEAKER — "The Environmental Crisis and Science" — Mr. Albert Trakowski, Deputy Assistant Administrator for Programs Research, Research and Monitoring Office, Environmental Protection Agency, Washington, D.C.

MIXER FOR COLLEGIATE ACADEMY

PANEL DISCUSSION BY SENIOR ACADEMY — "Undergraduate Science Requirements"

Saturday, April 17, 1971

COLLEGIATE ACADEMY — Business Meeting

SENIOR ACADEMY — Business Meeting

COLLEGIATE ACADEMY — Papers

SENIOR ACADEMY — Papers

COLLEGIATE ACADEMY PROGRAM AND ENVIRONMENTAL SYMPOSIUM

Friday, April 16

JOHN HOLSTON, President, Collegiate Academy
"Environmental Responsibilities"

DR. ROBERT BABCOCK, Associate Director, Arkansas Water Resources Research Center — "Responsibilities of the Federal Government in Water Environmental Problems"

MR. JAMES McHANEY, Attorney, Arkansas Pollution Control Commission — "Responsibilities of the State Government in Environmental Problems"

DR. BOB RILEY, Lieutenant Governor — "Responsibilities of the Politician in Environmental Problems"

M. PRATT REMMEL, Director, Arkansas Ecology Center—
"Responsibilities of Citizen Groups in Environmental Problems"

DR. ROBERT KIRKWOOD, President, Arkansas Academy of Science — "Responsibilities of Scientists in Environmental Problems"

SUMMARY — John Holston, Dr. Joe Nix presiding
Arkansas Academy of Science Dinner. Speaker:
MR. ALBERT TRAKOWSKI, Deputy Assistant Administrator for Programs Research, Research Monitoring Office, Environmental Protection Agency.

SECTION PROGRAMS

SCIENCE EDUCATION SECTION

Chairman: Clark McCarty

FRANK L. SETLIFF: The Preparation of O-Fluorobenzoic Acid. An Elementary Organic Laboratory Experiment

Business Meeting

EDWARD E. DALE, JR.: A Course, Man and His Environment, at the University of Arkansas

JOE M. GUENTER: Physics and Environmental Studies

Panel Discussion, "Undergraduate Science Requirements"

ROBBIN C. ANDERSON, University of Arkansas, Fayetteville

ROBERT T. KIRKWOOD, State College of Arkansas

JOSEPH E. PRYOR, Harding College

ANTHROPOLOGY SECTION

Chairman: Mrs. Katherine J. Hardie

KENNETH W. COLE: A Consideration of Macro-climatic and Macro-biotic Change in the Ozark Highlands During Post-Glacial Times

RAYMOND CARL MEDLOCK: The Prehistoric Distribution of Bird Motifs in the Southeastern United States

Business Meeting

GLORIA A. YOUNG: Environmental Adaptions: The Otomi Indians of the Mezquital Valley, Mexico

ALBERT GOODYEAR: The Significance of the Dalton Adze in Northeastern Arkansas

MICHAEL YARBOROUGH: Earspools in the Southeastern United States; Typology and Sequence

PATRICK MARTIN: Historical Archaeology in Arkansas

BIOLOGICAL SCIENCES

Biology Division

Chairman: Bryce Roberson

S. H. DUKE and F. E. LANE: Effects of Radiation on IAA-oxidase of Alaska Peas

S. D. BRYANT and F. E. LANE: An Electrophoretic Exa-

mination of the Isozyme Nature of IAA-oxidase from Alaska Peas

EUGENE B. WHITTLAKE: The Androstrobilus of *Glyptostrobilus europaeus* (Brongn.) Heer

JIMMIE D. BARRACK and LEO J. PAULISSEN: Demonstration and a Suggested Immune Role of Mouse Antibodies Against *Salmonella enteritidis* Endotoxin

RICHARD L. MEYER: Notes on the Algae of Arkansas I. *Chrysococcus*, *Kephyrion*, *Pseudokephyrion* and *Stenokalyx*

WILLIAM F. EVANS: A Facility for the Biological Treatment of a Complex Chlorophenolic Waste

DANIEL L. MARSH: Studies of Arundinaria: Experimental Induction of Flowering and Additional Observations in the Field

DALE V. FERGUSON and NORMAN N. DURHAM: "Actinomycin D Inhibition of Amidase Synthesis by *Pseudomonas fluorescens*

HUGH A. JOHNSON: Longevity of *Sclerotinia camelliae* in Culture

MICHAEL IVOR JOHNSON: A Survey of the Vascular Flora of Poinsett County, Arkansas

Business Meeting

BIOLOGICAL SCIENCES

Zoology Division

Chairman: Jack Wood Sears

JOHN K. BEADLES, JOHN M. RANSON JR., HALDOR M. WILKES: Growth-rate Studies of Channel Catfish, *Ictalurus punctatus*, (Rafinesque)

GLENN H. STANLEY and HENRI D. CROWLEY: Ratio of Adult to Immature Mourning Doves, *Zenaidura macroura*, Killed on Holla Bend National Wildlife Refuge, 1970

GARY A. HEIDT: Behavioral Aspects of a Two-Legged Raccoon, *Procyon lotor*

LELAND F. MORGANS: The Effects of Urethan on Fish Epithelial and Fibroblast Cells in Vitro

CHARLES L. SELMAN and HARVEY E. BARTON: The Relative Abundance, Seasonal Distribution, and Taxonomy of the Sphingidae of Northeast Arkansas"

Program

DOUGLAS M. ROGERS: Some Effects of High Density Fish Culture Upon Eutrophication of a Reservoir Lake

PEGGY R. DORRIS: Phosphorescent Animal Forms of Arkansas

HENRY W. ROBISON and GEORGE L. HARP: A Pre-impoundment Limnological Study of the Strawberry River in Northeastern Arkansas

JAMES T. JENKINS and GEORGE L. HARP: Ichthyofaunal Diversification and Distribution in the Big Creek Watershed, Craighead and Greene Counties, Arkansas

REX L. ELEY: Discharge Regimes, Density Currents, and Reservoir Water Quality

Business Meeting

CHEMISTRY SECTION

Chairman: W. D. Williams

JAMES O. WEAR: Rapid Electroosmosis Measurements

MRS. B. BARNETT and T. D. ROBERTS: Synthesis, Photolysis and Thermolysis of Formanilides

Business Meeting

DOMINIC T. C. YANG, B. J. WILSON, T. M. HARRIS and M. R. BOYD: Toxic Metabolites Derived from Fungus-Contaminated Sweet Potatoes (*Ipomoea batatas*)

EDMOND W. WILSON, JR. and R. BRUCE MARTIN: Circular Dichroism of Metal-Ion Peptide Complexes

W. METTETAL and T. D. ROBERTS: Approaches to 9, 10-Phenanthrocylopropenyl Systems

RICHARD S. MITCHELL, GEORGE L. HARP, GENE W. REID, and DONNA F. J. HAMMETT: Analysis of Bauxite Strip Mine Lakes

MATHEMATICS SECTION

Chairman: Dean Priest

R. H. BOWMAN: Jet Bundles on Smooth Manifolds

R. E. JOHNSON: A Characterization of Hilbert Space

Business Meeting

J. L. LINNSTAEDER: A Classical Multi-stage Control Problem

C. H. SCANLON: The Riemann Complete Integral

R. L. TANGEMAN: Generalized Boolean Rings

PHYSICS SECTION

Chairman: James E. Mackey

DONALD A. MITCHELL: Observation of Fine Structure Transitions in Hydrogen

HOWARD KISNER: Collision Destruction of Fast Hydrogen Atoms in the 3s State

Business Meeting

J. G. WEBB: The Kohn Approximation for Scattering Phase Shifts

THOMAS O. CALLAWAY: X-Ray Diffraction Techniques as Applied to Liquid Metals

Collegiate Academy — Minutes, Financial Report and Abstracts of Papers

MINUTES

Minutes for the April 17 meeting—John Holston presiding—were read. A nominating committee was appointed with Mark Wilson as chairman of the committee. It was voted to appoint a constitution committee with one representative from each school. The motion was passed to continue to abolish membership fees.

A motion was made by Dr. Don England to place the term of the sponsors of the academy on a two-year basis with the election of one new sponsor each year. In order to implement this plan, Dr. England submitted his resignation as sponsor of the academy. The motion was passed and Dr. Neal Robotham was elected to serve with Dr. Joe Nix as co-sponsors.

Ideas to stimulate interest in the academy were discussed and the opinions on continuing the two-day meeting were taken.

The motion was made and passed to extend the term of the president to June 1 in order to allow him to finish the business of the present school year.

New officers were elected and were

Ronald Sexton of College of the Ozarks—President-elect

Randy Smith of Harding—Treasurer

Ramona Rice of Ouachita University—Secretary

The meeting adjourned after the introduction of the new president, Neal Sumerlin of Ouachita University.

Respectfully submitted,

Ramona Rice

Financial Report

1970-7971

Balance September 1	\$ 156.39
Expenditures	
Postage	20.00
Scientific American Subscriptions (2)	20.00
Travel expenses	23.10
	<hr/>
TOTAL EXPENDITURES	\$ 63.10
Balance June 1	\$ 93.29

PHYSICAL SCIENCES SECTION

STEVE WEST and JOHN HOLSTON: The Distribution of Dissolved Oxygen in DeGray Reservoir.

The dissolved oxygen distribution in the new DeGray Reservoir on the Caddo River, Arkansas has been studied since impoundment began in August 1969. The oxygen distribution can be used to indicate mixing patterns within the reservoir. The classical picture of reservoir turnover is not indicated by the data during the period of this study. Oxygenation of the hypolimnetic zone of this reservoir apparently occurs by the underflow of cool winter rains.

RAMONA RICE: A Modification of the Ultraviolet Spectrophotometric Determination of Nitrates in Natural Waters.

Nitrate determinations are a useful parameter of the evaluation of water quality. Spectrophotometric methods used to measure nitrates at 210 nanometers all have some inherent problems. The only interfering factor present in normal surface water in Arkansas is dissolved organic material which also contributes absorbance in the ultraviolet range.

Use of activated carbon to remove interfering organic material and the subsequent measurement of nitrates has been evaluated.

RON CLARK: Dispersion of Electromagnetic Radiation.

Cauchy derived the first empirical equation describing dispersion. Sellmeier and Helmholtz followed with even better empirical equations. Later a dispersion equation was derived theoretically using electromagnetic theory.

A study was made of the effect of changing the concentration of sodium chloride in a water solution on the dispersion of visible light through the solution. It was shown that the dispersion of the solution increased linearly with the increase in percent salt in solution.

CAROLE McCORRY: Preparation and Properties of Strontium Monofluorophosphate Monohydrate.

A study has been undertaken of the chemistry of fluoro-phosphate compounds with emphasis on the experimental preparation and properties of strontium monofluorophosphate monohydrate, $\text{SrPO}_3\text{F} \cdot \text{H}_2\text{O}$.

Arkansas Academy of Science

The compound was prepared by precipitation from a solution of stoichiometric amounts of sodium monofluorophosphate and strontium chloride. Analysis for strontium, total phosphorus, total fluorine, and fluorophosphate indicated a high purity product which crystallized from aqueous solution as the monohydrate.

Further study showed the crystals to be only slightly soluble in water and insoluble in a number of organic solvents. At 23° C the solubility in water was 0.0554 moles of the monohydrate compound per liter of solution. The compound was dehydrated by heating at reduced pressures. Attempts to obtain X-ray patterns on the monohydrate or the anhydrous compound were unsuccessful.

KEITH McMABL: Topics In Group Theory.

This paper is a study of a few selected topics in group theory. The first chapter deals with the special subgroup of a group. It presents proofs to six theorems concerning the subgroup and includes a discussion of a particular example. The second chapter exhibits solutions to two problems concerning finite groups.

The final chapter is devoted to topological groups. It presents results concerning products of topological groups, separation properties, the quotient topology, and isomorphism theorems applied to topological groups.

RONALD K. PEARSON: Eddy Currents Induced In a Copper Pendulum.

This experiment was to determine the nature of eddy currents induced in a copper disc pendulum swinging through a magnetic field and to determine their possible usefulness.

The apparatus employed in this experiment consisted of a copper disc pendulum, a strong electromagnet and a galvanometer for measuring the induced currents.

These currents were alternating currents whose frequency was dependent upon the period of the pendulum and whose magnitude was dependent upon the strength of the magnetic field, the geometry of the copper disc, and the instantaneous velocity of the pendulum.

MARTIN TULL: Practical Holography.

The intent of this paper is not to dwell in the theory of holography, but rather to attempt to introduce into general knowledge many of the problems encountered when actually setting up and exposing holograms. Along with problems, both workable techniques and cost-time saving short cuts will be discussed. The procedures absolutely necessary to obtaining good results will be separated from those which have less bearing on the production of acceptable holograms.

NEAL SUMERLIN: Radiochemical Studies of Cs¹³⁷ in Rain.

Radiocesium data in rain obtained at Fayetteville,

Arkansas during the past five years has been brought up to date, compiled and compared with Sr⁹⁰ data from the same period. The difference in fallout rates after individual nuclear detonations and in the stratospheric mean residence times is explained on the basis of relative volatility of the mass chains producing the two nuclides. The influence of the series of Chinese nuclear tests on the long-term observed concentrations of Cs¹³⁷ and Sr⁹⁰ is discussed.

DONNA HAMMETT: Aluminum Analysis of Bauxite Strip Mine Lakes.

The water of four strip mined lakes near Bauxite, Arkansas were analyzed for their aluminum content by spectrophotometry. Ion measurements cover the period from September, 1969 to September, 1970. A profile analysis was made in June, 1970. The fluctuations in the ion concentration are discussed.

DAVID BYRD: Computer Solution of Linear Programming Problems.

A FORTRAN program was written to solve linear programming problems. The program utilizes the simplex algorithm. The program is designed to handle an objective function of up to one hundred variables subject to fifty constraints. The program has been run successfully on an IBM 360/30.

CARL BAKER: The Synthesis of 3(O-Hydroxyphenyl)-Indolizidine.

The synthesis of the indolizidine involved two steps. First, it was necessary to synthesize 2-pyridal-o-hydroxyacetophenone by a crossed aldol condensation. Improved methods tripled the yields reported in the literature. Secondly, the acetophenone compound was reductively cyclized with Pt₂O and acetic acid in a hydrogenator to produce the indolizidine. Purification was accomplished in both cases by recrystallization from hot methanol.

Chromatographic studies and melting point determinations indicated the purity of the product; infrared and nuclear magnetic resonance spectra gave evidence to the structural properties of the final compound. Studies are now being conducted to determine biological activities (indolizidine compounds have been known to have effects on the cardio-vascular system).

JAN RUTHERFORD: Influence of Hydrophile-Lipophile Balance (HLB) Values on Drug Release From Emulsified Systems.

The release characteristics of a water-soluble dye Amaranth from emulsion type bases as they were affected by the hydrophile-lipophile nature of the emulsifier present were investigated. The emulsions were of oil-in-water types using mineral oil and water. The surfactants used were Tween 60 and Arlacel 60 in varying weight proportions. An optimum release of the dye was

found to be at the HLB values of 8, 9, and 10. This was thought due to the surface adsorption of Amaranth in the interface to the surfactant.

BIOLOGICAL SCIENCES SECTION

MARK BOWLES, JOHN HOLSTON, and GABRIEL SROUJI:
The Effect of EDTA and Fructose on the Distribution of Mn^{54} in Rabbits.

Rabbits were injected with solutions of Mn^{54} to determine the relative deposition of the radioactive isotope in various organs.

The solutions were treated with chelating agents to determine their effect on the distribution of Mn^{54} .

JOE CARROLL: An Ecological Comparison of Two Municipal Bioxidation Ponds.

Community metabolism, bacteria numbers, and several water quality parameters were measured in the inflow, outflow, and oxidation pond of the two sewage treatment plants of Magnolia, Arkansas. Photosynthesis accounted for less than 4% of the total oxygen gains in the oxidation pond of treatment plant 1, while photosynthesis accounted for over 95% of the total oxygen gains in the oxidation pond of treatment plant 2. Treatment plant 1 received an industrial effluent that apparently was toxic to phytoplankton. The toxic compound was identified as a phenol-formaldehyde polymer by ultra-violet and infrared spectra.

Frank L. Setliff

The Preparation of o-Fluorobenzoic Acid. An Elementary Organic Laboratory Experiment

Frank L. Setliff

Department of Chemistry

University of Arkansas at Little Rock

Little Rock, Arkansas 72204

ABSTRACT

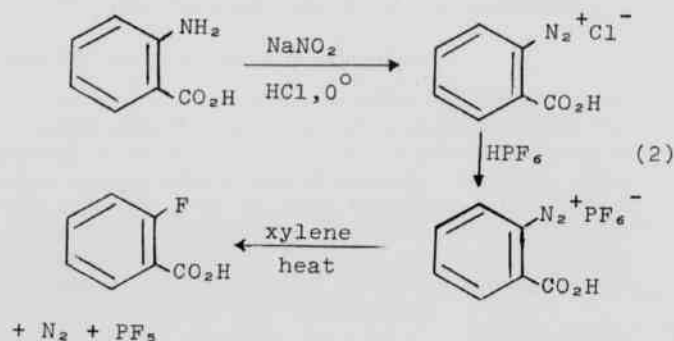
An experiment designed for organic chemistry students at the sophomore level is presented. The experiment, which involves no special equipment and which employs only inexpensive reagents, demonstrates the conversion of anthranilic acid to o-fluorobenzoic acid via the modified Schiemann Reaction.

Although most elementary organic texts illustrate the introduction of fluorine into aromatic systems by the Schiemann Reaction,^{1,2} (equation 1) no experiments are generally available for the student laboratory application of this reaction.



Rutherford and co-workers³ observed that replacement of fluoboric acid (HBF₄) with hexafluorophosphoric acid (HPF₆) in the above reaction resulted in improved overall yields of aromatic fluorides. The most outstanding yield increase (+52%) was in the case of the conversion of anthranilic acid to o-fluorobenzoic acid.

We have found that the general procedure employed by Rutherford is, with some modification, suitable for the preparation of o-fluorobenzoic acid in the elementary organic laboratory. The overall reaction scheme is illustrated by equation 2.



The experiment is conveniently performed in two laboratory periods. Diazotization of anthranilic acid and subsequent isolation of the o-carboxybenzenediazonium hexafluorophosphate is performed in the first period, and the second period is utilized for the thermal decomposition of the diazonium salt. The decomposition step proceeds smoothly, and students find it an interesting chemical transformation to observe.⁴

Experimental

To a solution of anthranilic acid (10.3 g, 0.75 mole) dissolved in water (53 ml) and conc HCl (7.5 ml) in a 400 ml beaker cooled to -5° (a ppt of the hydrochloride results) is added NaNO₂ (6.1 g in 20 ml H₂O dropwise from a separatory funnel) over a 30 min period with manual stirring. Hexafluorophosphoric acid⁵ (25 ml of 65%) is added in one portion from a polyethylene graduate cylinder to the cold, now gelatinous, diazotized mixture. After allowing the resulting slurry to stand at ice bath temperature for 1/2 hr, the white solid is suction filtered, washed on the filter pad with ice water (150 ml), sucked dry, and air dried until the next laboratory period (mp. 125-129°, dec; yield 13-15 g).

Decomposition is carried out in a standard taper 500 ml, round-bottomed, one-necked flask containing 200 ml xylene and equipped with a condenser and inverted funnel gas trap⁶ leading to a beaker of dilute NaOH solution. The mixture is heated with a small flame and with manual agitation until decomposition of the salt begins (evolution of white phosphorus pentafluoride fumes. WARNING: PF₅ is intensely irritating to skin, eyes and mucous membranes. Inhalation may cause pulmonary edema. Students should be thoroughly warned of this danger, each apparatus individually inspected by the instructor and the decomposition performed in an efficient fume hood). As decomposition ceases, the xylene is heated to boiling for 5 min to expel the excess gases. The reaction mixture is cooled to room temperature, extracted with three 50-ml portions of 5% NaOH

solution, and the aqueous extracts are poured with stirring into a slush of ice (100 g) and conc HCl (100 ml). The precipitated acid is suction filtered, washed on the filter with ice water (150 ml), dried, and recrystallized from methylcyclohexane (15 ml/g) using a steam cone. The yield of light yellow solid is 4-5 g, (40-50% from anthranilic acid), mp 120-122° (lit^s mp 124-125°).

References

1. Balz, G., and Schiemann, G., *Chem. Ber.*, **60**, 1186 (1927).
2. Roe, A. in "Organic Reactions," Vol. V, J. Wiley and Sons, Inc., New York, 1949, p. 193.
3. Rutherford, K., Redmond, W., and Rigamonti, J., *J. Org. Chem.*, **26**, 5149 (1961).
4. Unlike some aromatic diazonium salts which have been reported to be shock sensitive, diazonium fluoborates and hexafluorophosphates have been found to be remarkably stable in this respect. Furthermore, the success of their use in synthesis is based upon their stability and ability to be smoothly decomposed.
5. Obtainable from the Ozark Mahoning Co., Tulsa, Oklahoma. This reagent will etch glass on prolonged contact. However, we have observed no glassware damage if students thoroughly wash all glassware in previous contact with the acid.
6. c. f. Dannley, R. and Crum, J., "Experimental Organic Chemistry." The Macmillan Co., New York, 1968, p. 29.

Physics And Environmental Studies

Joe M. Guenter

The Physical Science Department

University of Arkansas at Monticello 71655

ABSTRACT

To further implement the course curriculum for the Earth Science major and to constructively channel the current interest and concern with the environmental problems, the Department of Physical Science at the University of Arkansas at Monticello introduced a course entitled Environmental Studies this past spring.

As it was necessary to offer both a general education Elementary Physics course in addition to the new course, it was decided to combine the two courses and use an approach similar to that of Edwin Marston, Queens College, Flushing, New York.

Problems of conservation, pollution, and environmental quality were considered by the class whose rank ranged from freshman to senior with widely diverse backgrounds. Physics with minimal math was incorporated sporadically as needed.

The basic structure of class organization allowed students of the Environmental Studies class to present panel discussions for the other students to participate in through comments, questions, and answers.

The process of implementing the planned Earth Science major curriculum began two years ago at Arkansas A&M College, now the University of Arkansas at Monticello. The program, which is one of the offerings of the Department of Physical Science, gained several majors and minors and matured rapidly.

This past fall it was realized that the single person devoted to the earth science and geology area could not offer all of the general and advanced courses currently needed. As finances would not permit the addition of another faculty member at that time and as there was one member on leave for the academic yer, faculty time was at a premium.

A general education physics course was to be offered and an additional upper level course for those majoring or minoring in Earth Science was needed for the fall semester. It was, therefore, decided to introduce one of the previously formulated courses, Environmental Studies, at this time. It was further agreed that the two courses, Elements of Physics and Environmental Studies, would be combined and taught together. The temporary combining of these two courses was the apparent solution to the situation previously indicated.

This approach was not altogether unique as Dr. Edwin Martson, Queens College, Flushing, New York, had described an innovative course in an article in the

American Journal of Physics, Vol. 38, No. 10. His course is entitled "Physics of Urban and Environmental Problems" and involves the consideration of problems relating to transportation, air pollution, water pollution, and the scarcity of resources.

Two problems were immediately manifested. First — the wide range of experience and rank (freshman to senior) of the students who would take the course and second — the difference in preparation and requirements for the two courses. No prerequisite is required to take the physics course while six hours of science and junior or senior standing are the prerequisites for the earth science course. These problems, however, were looked on as possible advantages in that a variety of ideas, experiences, and backgrounds could result in fruitful discussion involving many areas and view points.

In relation to the different requirements for the two courses, the following approach was followed: Those qualified to take the Environmental Studies course would serve as "experts" on panels to discuss problems on air pollution, water pollution, etc. In addition, they were required to submit a term paper on a related topic of their choice.

A communication with Dr. Marston resulted in a sampling of tests, problems, and information handouts containing needed mathematics, work, energy, and power relationships. These and numerous other handout material composed the "text" for his course, supplemented by paperback readers to provide background in the areas of population, food, and energy problems.

The primary topics for our program which the panel discussions dealt with were air, food, land, and water quality.

The presentations of the panel discussions involved approximately half of the class including several students for which this was not a requirement. As the majority of the students were majoring in either biology or earth science, there was great emphasis placed on these areas throughout the presentations and discussions.

In addition to presenting very enlightening facts, figures, and data, the panels led the class in reaching some significant, tho not perhaps unique, decisions and conclusions.

The presentation by those students speaking on air quality included sources of air pollution and the effects on both plant and animal life along with possible controls and predictions of what might occur if nature becomes too far out of balance. As air pollution problems are somewhat more obvious than some others, in the Southeast Arkansas area, much interest was generated and concern was expressed as to what was actually being done. One of the more enterprising students was instrumental in having a pollution control agent investigate one of the local industries. He also circulated

petitions requesting the industry to cut down significantly on the rate of emission of particles released into the air.

Another group of students discussed areas relating to food additives, preservatives, nutrition, and the FDA. Other topics were the use and misuse of drugs, and contaminants such as mercury, DDT, etc. The conclusion reached here was to be careful of whatever you put into your system.

Water quality was presented by a fourth panel. The use made of water by animal and plant, agriculture and industry; and its many other complicated interactions in the ecosystem was cited. Other problems such as sewage treatment plants and the nutrafication of a lake were explained. The group pointed out what can be done, what is being done, and what will happen if things continue to deteriorate as they are now doing.

Those discussing land problems took a conservation approach citing damage caused by draining swamps and streams, complications caused by over-population, disposal of solid waste, destruction by strip mining, and pollution by pesticides and insecticides.

Conclusions — slow down on dam building, swamp drainings and river channelization — initiate recycling programs — and look to other methods of pest control, i.e., biological or physical, etc.

The preparations and presentations of the discussions gave not only the panelists, but also the other students new and deeper insights into the problems and complications involved and to the difficulties in applying some of the controls for the solutions. A good example of this occurred when one panelist advocated the banning of pesticides and insecticides to prevent further contamination of food and water. This was countered with the fact that if these chemicals were not used to control weeds and insects then, there was a good possibility that many of the smaller farmers would not be able to stand the loss in yield and still make a living. This predicament was never fully resolved.

Concerning the physics, most of it was introduced toward the end of the course to allow the student time to develop some confidence in himself, the course, and the teacher before 'frightening' him with formulas and relationships. This was a mistake. More physics should have been introduced sooner as time ran short and there was not time enough to treat the physics sufficiently.

A voluntary and unisigned evaluation submitted by the students primarily corroborated many of the author's opinions concerning the course.

1. The majority of the students approved of both the panel discussions and of the term paper as beneficial to the course.
2. They were somewhat more neutral in their opinion as to whether there were too many topics

covered and the extent of coverage.

3. Although they complained about the problems and were not sure if the problems aided their comprehension, they agreed that they were well explained and were of the right level of difficulty and number.

Though the grades ran reasonably high, many students requested more tests (there were two) and more ecology in the course.

As we will have all of the faculty back on campus

next year, we will be able to offer the courses separately next spring. This will enable us to infuse more physics into the Elements of Physics course and more ecology into the Environmental Studies course. However, we will incorporate a great deal of the study of environmental problems and quality which had not been done prior to this innovation. This time the physics course was somewhat squeezed into the environmental mold. The next time the introduction of pollution topics will serve as a relevant starting point from which to move readily into contributing areas of physics.

A Consideration Of Macro-Climatic And Macro-Biotic Change In The Ozark Highlands During Post-Glacial Times

Kenneth W. Cole

Arkansas Archeological Survey

Box 1361, Arkansas Polytechnic College

Russellville, Arkansas 72801

ABSTRACT

Climatological, pedological and faunal investigations conducted in the Upper Midwest and the Ozark Highlands indicate that the environment to which man in the Ozarks was adapting over the past 12,000 years has undergone several major shifts, beginning with a cool-moist boreal forest situation followed by a period of warming and aridness resulting in prairie and deciduous forest climaxes and subsequently, in the last 4000-5000 years, change to the pattern reflected by present conditions.

INTRODUCTION

Paleoecology and climatological episode investigations for the Ozark Highlands physiographic, geographic and archeologic province are a necessary prerequisite in understanding the cultural development and variability manifest in archeological assemblages derived from the Ozarks. Studies of this nature have been prevalent in the Upper Midwest and northern Ozark periphery for the last decade. Notable undertakings are: 1) Cleland's study of "The Prehistoric Animal Ecology and Ethnozoology of the Upper Great Lakes Region" (1966) and Yarnell's related report of "Aboriginal Relationships Between Culture and Plant Life in the Upper Great Lakes Region" (1964); 2) the multi-disciplinary investigations of bogs and archeological sites, particularly Rodgers Shelter, in western Missouri as part of the program focusing on

"The Archeology and Paleoecology of the Western Ozark Highlands" and involving the geochronologist C. Vance Haynes, the mammalogist Paul W. Parmalee, and the palynologist Peter J. Mehringer, Jr. (Wood and McMillan 1967); 3) Klippel's investigation of "Prehistory and Environmental Change along the Southern Border of the Prairie Peninsula during the Archaic Period (1971); 4) Falk's study of unmodified animal bone from a stratified cave in the Northern Missouri Ozarks (1970); and 5) the recently funded National Science Foundation project to undertake a paleoenvironmental study of the Sangamon River Valley in Illinois. These and the multitude of other paleoecology investigations not mentioned are indicative not only of what is being done but what can be learned relative to prehistory through research directed toward the interrelationship between man and his environment.

Kenneth W. Cole

The purpose of this paper is to consider some of the statements made about the paleoecology of the Ozarks. Involved will be summarization of several current interpretations of broad geographic and chronologic scope overlapping the geographic Ozarks and the period of Indian occupancy in an attempt to state knowledge of post-Pleistocene physiographic, meteorologic, zoic and floristic change, integrate what is known, and relate it regionally.

GEOGRAPHY

The Ozark Plateau physiographic province, variously called the Ozark Highlands or simply the "Ozarks", falls geographically into portions of five states. The Illinois, Kansas, and Oklahoma units are small in areal extent and are considered only incidental to the Arkansas and Missouri portions of the Plateau. Sauer (1920: 3) estimates that only 6% of the Ozarks are contained within the northeast corner of the political division of Oklahoma, and only 2% are contained within the combined areas of the extreme southeast corner of Kansas and the Shawnee Hills of Illinois (cut off from the main units of the Ozarks by the Mississippi River). Sixty-six percent of the plateau falls within Missouri, and 26% of the territory is contained within Arkansas. Limits of the Ozarks are best defined by river breaks between physiographic units — the Spring, Neosho, and Arkansas River system on the extreme west in Oklahoma, Kansas, and Missouri; the Cherokee Plains, or Sac and Osage rivers on the Northwest; the Missouri River Valley along the north; the Mississippi River Valley along the northeast; the tertiary alluvial deposits of the Mississippi Embayment along the southeast; and the Arkansas River Valley along the south (Figure 1). An estimated 50,000 square miles are delimited by these peripheral units, forming a parallelogram running roughly northeast-southwest in maximum linear direction (Sauer 1920: 3). The Missouri unit covers almost the entire southern half of the state, and the Arkansas unit covers the northwest quadrant of that state. Within this border are numerous areas defined on the basis of topographic-biotic features, the primary ones being the Boston Mountains, Springfield Plateau, Salem Plateau, St. Francois Mountains, and Huntsville Prairie.

MODERN BIOTIC PROVINCES

Dice (1943) has included the Ozarks as a portion of his Carolinian Biotic Province yet recognizes that it does possess biotic district status, indicating some dissimilarity with the major unit of the province located east of the Mississippi River in the northeastern United States. Carolinian is characterized as a deciduous forest zone of diversified hardwood (mainly oak-hickory in the Ozarks with a subclimax of pines). Within the district, at least three phases of oak-hickory or oak-pine occur — dry ridge phase, slopes phase, and lowland phase — with xeric glade situations characterized by buckthorn and juniper occurring in certain areas (Moore 1960: 6;

Gary Tucker, personal communication). Prairies also exist within the Ozark district of the Carolinian Province, and are basically tall-grass habitats comparable to those of Oklahoma and Kansas.

The Carolinian Biotic Province is distinguishable from the Illinoian mixed prairie-deciduous forest province to the northwest, with the transition gradual in some places and abrupt in others. The Texan prairie-mixed-with-hardwood province to the west, with its distinctive fauna, and the Ouachita and Mississippi districts of the Austroriparian province, with their pine and hardwoods, provide the remaining surrounding zones, although, again, biotic boundaries are diffuse and the Ozark district is best defined physiographically. Climatic shifts could easily lead to encroachment of the three surrounding biotic provinces into the Ozarks, or vice-versa.



Figure 1. Map of the Ozark Highlands geographic, physiographic, biotic and archeologic province.

Bryson and Wendland, approaching climatic patterns from a meteorological direction, assume that "within the past ten or fifteen millenia a mix of air masses occurring in the same frequency and annual sequence as at present would be associated with a similar biotic system to that with which it is now associated" (1967: 277) and that "past climates differed from present climates in quantity, but not in kind" (1967: 277). Approaching paleoenvironmental conditions from a biotic

viewpoint, the paleobiotic provinces need not necessarily be identical with modern Dician biotic provinces, but are generally considered to be similar enough so that modern correlates can be used to provide a more complete environmental picture for the past.

MACRO-CLIMATIC EPISODES IN THE MIDWEST

Several schema of climatic episode patterns with corresponding faunal-floral conditions have been formulated for the upper Midwest, focusing primarily on the Great Lakes Region or the northern portion of the upper Midwest — Griffin (1961), Bryson (1965), Baerreis and Bryson (1965), Bryson and Wendland (1967), Cleland (1966), and Wright (1968). Although concerned primarily with geographic zones north of the Ozarks, Baerreis and Bryson (1965) consider that if an identified climatic episode and related biota exist in

one geographic area, a corresponding episode, not necessarily the same, will be occurring elsewhere, and that, in fact, the climatic conditions of the past are globally interrelated. Therefore, climatic fluctuations recorded in the archeological-paleoenvironmental record for the upper Midwest must be reflective of conditions and chronology in the Ozarks, especially since the latter area lies on the southern border of the meteorologically defined regions of the north.

Since no satisfactory record of climatic succession exists for the Ozarks, outside of the one presently being formulated for northern Ozark border zones, these schema of episode information of various mentioned authors are presented only in summary form (Figure 2) and correlation is graphically established. The correspondence of these episodes with the only investigated Ozark area, the northern periphery, has been considered elsewhere (Klippel 1971: 43-46) and satisfactory correlations determined.

NEOTHERMAL	UPPER GREAT LAKES REGION Cleland (1965) and Griffin (1961)		UPPER MIDWEST Bryson (1965), Bryson and Wendland (1969)												
<p>ANATHERMAL</p> <p>Cool moist</p> <p>5500 B.C.</p>	<p>BOREAL WOODLAND PERIOD: 12000-9000 B.C. Glacial retreat and advance; cold glacial climate; spruce dominated forest with trace of deciduous forms; cold weather fauna including extinct forms.</p> <p>BOREAL FOREST PERIOD: 9000-7000 B.C. Warmer climate; closed boreal forest with deciduous elements.</p> <p>PINE FOREST PERIOD: 7000-3500 B.C. Climate becoming warmer, passing present level (Xerathermic); spruce-pine forest changing to pine with oak-pine in the south.</p>		<p>LATE GLACIAL CLIMATE EPISODE 11000-8000 B.C. Cool-Moist Boreal forests</p> <p>BOREAL EPISODE 8000-6000 B.C. Warm-dry; grassland with pine changing to oak savannah (forest-prairie)</p>												
<p>ALTITHERMAL (HYPITHERMAL)</p> <p>hot dry</p> <p>2000 B.C.</p>	<p>OAK AND PINE PERIOD: 3500 B.C. to Present Warmer-dryer climate; Carolinian Biotic Province establishment; oak-hickory forest dominant in south with associated fauna.</p> <table border="0" style="width: 100%;"> <tr> <td style="width: 50%; text-align: center;">Griffin</td> <td style="width: 50%; text-align: center;">Cleland</td> </tr> <tr> <td>2300-1800 B.C. — Warm Middle Archaic Florescence</td> <td>Xerothermic Maximum</td> </tr> <tr> <td>1800-1300 B.C. — Cool</td> <td>Cool Episode</td> </tr> </table>		Griffin	Cleland	2300-1800 B.C. — Warm Middle Archaic Florescence	Xerothermic Maximum	1800-1300 B.C. — Cool	Cool Episode	<p>ATLANTIC EPISODE 6000-3000 B.C. Warm-dry; climax forest</p> <p>EARLY SUB-BOREAL EPISODE 3000-1500 B.C. Warm-dry</p> <p>LATE SUB-BOREAL EPISODE 1500-550 B.C.</p>						
Griffin	Cleland														
2300-1800 B.C. — Warm Middle Archaic Florescence	Xerothermic Maximum														
1800-1300 B.C. — Cool	Cool Episode														
<p>MEDITHERMAL</p> <p>relatively cool moist</p>	<table border="0" style="width: 100%;"> <tr> <td style="width: 50%;">1300-800 B.C. — Warm Late Archaic Expansion</td> <td style="width: 50%;">Late Archaic Episode</td> </tr> <tr> <td>800-300 B. C. — Cool</td> <td>Cool Episode</td> </tr> <tr> <td>300 B.C.-A.D. 300 — Warm Middle Woodland Expansion</td> <td>Hopewell Episode</td> </tr> <tr> <td>A.D. 300-800 — Cool Middle Woodland Decline</td> <td>Scandic Episode</td> </tr> <tr> <td>A.D. 800-1200 — Warm Middle Mississippi Expansion</td> <td>Neo-Atlantic Episode</td> </tr> <tr> <td>A.D. 1200-1700 — Cool Upper Mississippi Decline</td> <td>Proto- and Historic Episode</td> </tr> </table>		1300-800 B.C. — Warm Late Archaic Expansion	Late Archaic Episode	800-300 B. C. — Cool	Cool Episode	300 B.C.-A.D. 300 — Warm Middle Woodland Expansion	Hopewell Episode	A.D. 300-800 — Cool Middle Woodland Decline	Scandic Episode	A.D. 800-1200 — Warm Middle Mississippi Expansion	Neo-Atlantic Episode	A.D. 1200-1700 — Cool Upper Mississippi Decline	Proto- and Historic Episode	<p>SUB-ATLANTIC EPISODE 550 B.C.-A.D. 400 Wet; oak-hickory climax forest</p> <p>SCANDIC A.D. 400-900 — amelioration</p> <p>NEO-ATLANTIC A.D. 900-1200 — warm, wet PACIFIC I A.D. 1200-1450 — cool, dry PACIFIC II A.D. 14-50-1550 — Warmer NEO-BOREAL A. D. 1550-1850 — cool Recent A. D. 1850 to present — warmer</p>
1300-800 B.C. — Warm Late Archaic Expansion	Late Archaic Episode														
800-300 B. C. — Cool	Cool Episode														
300 B.C.-A.D. 300 — Warm Middle Woodland Expansion	Hopewell Episode														
A.D. 300-800 — Cool Middle Woodland Decline	Scandic Episode														
A.D. 800-1200 — Warm Middle Mississippi Expansion	Neo-Atlantic Episode														
A.D. 1200-1700 — Cool Upper Mississippi Decline	Proto- and Historic Episode														

Figure 2. Macro-climatic schema for western and Upper Midwestern North America.

Kenneth W. Cole

Specific data supportive of the pattern of post-Pleistocene climatic succession are rare for the Ozarks. Boney Spring from western Missouri has produced the only usable pollen spectrum overlapping the time period of concern. The late deposits (300 B.C. or less) indicate a biotic situation similar to the current Carolinian-Illinoian border, with the forest situation being one of oak-hickory and associated plant and animal species (Wood and McMillan 1969: 10). Pollen and macrofossils produced by a Boney Spring stratum with two radiocarbon dates — one $16,580 \pm 220$ BP and the other $13,700 \pm 600$ BP — produce a spectrum similar to that which existed in southwest Minnesota and northeast South Dakota during the interval 11,500 BP and 10,500 BP, and today is represented by isolated bog situations extending only as far south as central Wisconsin. Spruce (*Picea* sp.) dominates the spectrum, with Larch (*Larix laricina*) a present species (Mehring et al. 1968: 567). Pollen samples from Trolinger Bog are too early for consideration. The samples recovered from Rodgers Shelter as part of the same Western Ozarks project have produced little information at present, but analysis continues on the samples of this well-dated archaeological site.

Parmalee, Oesch, and Guilday (1969), approaching the paleoenvironment of the northern periphery of the Ozarks by using faunal data from cave contexts, conclude that:

... with the gradual warming trend, and with eventual establishment of the warm and dry xerothermic period (ca. 3500-1500 B.C.), this boreal environment and its related fauna disappeared from the Ozarks.

Associated with the termination of this moist, boreal environment and the beginning of the warm and dry xerothermic period was a major change in vegetation type. The coniferous forests were replaced with deciduous hardwoods, probably oaks and hickories being the dominant trees, and apparently large expanses of the Ozark Highlands became covered with short-grass prairie. Remains of pocket mice, grasshopper mice, and the kit fox recovered from Crankshaft Cave are indicative of a habitat now characteristic of the western and central Great Plains. These species probably survived in the Ozarks until the return of cooler and more moist conditions, which, in turn, permitted expansion of the hardwood forests and the establishment of tall-grass prairie and a mammalian fauna characteristic of the area today (Parmalee et al. 1969: 36).

Graham Cave, at the northern edge of the Ozarks, has recently been reinvestigated from a paleoecologic perspective. Klippel (1971) undertook pedological analysis of the cave deposits and correlated these with vertebrate fauna from the cave and the Prairie Peninsula to the north. Klippel's thesis is that changing environmental conditions are reflected in the cave deposits, erosional

patterns influenced by climate resulting in more wind-blown material deposited in the cave during dryer periods. Mechanical sorting of the deposits and analysis of particle size difference led Klippel to conclude that about 9500 years ago the climate was more moist and sand built up in the cave as ceiling fall. Following this was a climatic change towards a more arid situation allowing for increased wind erosion and eventual deposition of eolian material in the cave. Beginning around 5000 years ago, the deposits indicate a third change consistent with present environmental conditions (1971: 123-124).

Falk (1970), working in Arnold Research Cave in the same general area of Missouri as Graham Cave, undertook factor analysis of the faunal remains from the archaeological site and concurred with Klippel that a change is evident in the faunal record. Falk, however, prefers to attribute this variation over time to changes in the adaptive patterns of man, considering the cave context faunal assemblage to be primarily reflective of man's selection. While the vertebrate remains from the lower levels of the cave indicate an abundance of forest-habitat forms, and a forest-border fauna exists in the later Archaic and subsequent levels (1970: 31), we must be aware of the associated human parameters and not immediately conclude that the record is a product of biophysical environmental change.

Cleland (1965), concerned with the "reconstruction of the natural environment of an area as it was when this area was occupied by the culture in which we are interested", conducted faunal analysis of the resources recovered by the University of Arkansas between 1928 and 1934 from rock-shelters in Northwest Arkansas. He considers that "the great bulk of the material from the Ozark bluff shelters is probably a marginal and somewhat isolated manifestation of Late Middle Woodland and Middle Mississippi culture perhaps dating between A.D. 500 and A.D. 1400", and concludes that while forms of three habitats occur (all simultaneously for this area of the Ozarks) "no major change has taken place in either the composition or distribution of biotic communities since major occupation of the bluff sites" (1965: 70). Superficial evidence gained by recent investigations in the Ozarks indicates that the shelters were occupied over a much longer period of time than Cleland indicated, and that the remains used by him may reflect a longer time period characterized by greater micro-biotic variation and/or change.

These studies indicate how little we actually know about the paleoenvironment of the Ozarks except by inference from macro-schema or fringe area investigations.

CONCLUSIONS

Integration of the Ozark researches with the broader picture presented by the Midwestern paleoenvironmental schema leads to the following conclusions pertaining to

changing environmental and cultural patterns in the Ozark Highlands:

1) During man's initial occupancy of the Ozarks he was adjusting to an environment characterized by cool-moist climatic conditions and a boreal forest with associated fauna.

2) By 8000 B.C. the climate was becoming warmer and the boreal forests were being replaced by oak-hickory-pine phases with prairie expansion occurring in portions of the Ozarks. It was during this period that man was making his Archaic life-style adaptation to the Ozarks province.

3) Carolinian biotic province conditions were being established in the Ozarks by 3500 B.C., but of the Ozark district mixed-deciduous-forest-with-interspersed-prairie variety. Middle Archaic stage florescence was occurring during this period.

4) Following the Xerothermic maximum, a cooler, more moist climatic pattern prevailed in the Ozarks, typified primarily by a biotic situation comparable to that of the present but with numerous climatic fluctuations or perturbations occurring which would have altered the forest-prairie distribution. These perturbations are characterized as short-term fluctuations from cool to warm to cool. During this period of environmental fluctuation Woodland cultural elements diffused into the Ozarks, eventually being succeeded by Mississippian elements, possibly as a result of Middle Mississippi expansion occurring during the Neo-Atlantic Episode (A.D. 800-1200). Both adapted to the rugged terrain and mixed forest-prairie environment of the Ozarks.

5) Neo-Boreal cooling may have prompted migration of Mississippian populations out of the eastern Arkansas-Missouri area and into the Ozarks where, again, changes were made in the cultural pattern to adjust it better to the Ozarks.

6) All the above conclusions are based on data derived primarily from the northern Ozarks border with the prairie and are only tenable on this basis, subject to change as more basic environmental-cultural data accumulate for the remainder of the Ozarks.

REFERENCES CITED

- Baerreis, David A. and Reid A. Bryson
1965 Climatic Episodes and the Dating of the Mississippian Cultures. *The Wisconsin Archeologist*, Vol. 46, No. 4, pp. 203-220. Milwaukee.
- Bryson, Reid A.
1965 Recent Climatic Episodes in North America. *Proceedings of the Twenty-first Southeastern Archeological Conference, Bulletin 3*, edited by Stephen Williams, pp. 78-81. Cambridge.
- Bryson, Reid A. and Wayne M. Wendland
1967 Tentative Climatic Patterns for Some Late Glacial and Post-Glacial Episodes in Central North America. *Life, Land and Water*, edited by W. J. Mayer-Oakes, pp. 271-298. University of Manitoba Press, Winnipeg.
- Cleland, Charles E.
1965 Faunal Remains from Bluff Shelters in Northwest Arkansas. *The Arkansas Archeologist*, Vol. 6, Nos. 2-3, pp. 39-63. Fayetteville.
1966 The Prehistoric Animal Ecology and Ethnology of the Upper Great Lakes Region. *Anthropological Papers, Museum of Anthropology, University of Michigan*, No. 29. Ann Arbor.
- Dice, Lee R.
1943 *The Biotic Provinces of North America*. University of Michigan Press, Ann Arbor.
- Falk, Carl R.
1970 The Application of a Factor Analysis in the Interpretation of Unmodified Vertebrate Remains from an Archaeological Deposit in Central Missouri. Master's Thesis, University of Missouri, Columbia.
- Griffin, James B.
1961 Post Glacial Ecology and Culture Change in the Great Lakes Area of North America. *Publication Number 7, Great Lakes Research Division Institute of Science and Technology*. The University of Michigan, Ann Arbor.
- Klippel, Walter E.
1971 Prehistory and Environmental Change along the Southern Border of the Prairie Peninsula During the Archaic Period. Ph.D. Dissertation, University of Missouri, Columbia.
- Mehring, Peter J. Jr., Charles E. Schweger, W. Raymond Wood and R. Bruce McMillan
1968 Late-Pleistocene Boreal Forest in the Western Ozark Highlands. *Ecology*, Vol. 49, No. 3, pp. 567-568. Durham.
- Moore, Dwight M.
1960 *Trees of Arkansas*. Arkansas Forestry Commission, Little Rock.
- Parmalee, Paul W., Ronald D. Oesch and John E. Guilday
1969 Pleistocene and Recent Vertebrate Faunas from Crankshaft Cave, Missouri. *Reports of Investigations No. 14, Illinois State Museum*. Springfield.
- Sauer, Carl O.
1920 The Geography of the Ozark Highland of Missouri. *Geographic Society of Chicago, Bulletin No. 7*. Chicago.

Kenneth W. Cole

Wood, W. Raymond and R. Bruce McMillan

1967 Recent Investigations at Rodgers Shelter, Missouri. *Archaeology*, Vol. 20, No. 1, pp. 52-55. New York.

1969 Archeology and Paleoecology of the Western Ozark Highlands. *Final Report to the National Science Foundation*. University of Missouri Archeological Research. Columbia.

Wright, H. E., Jr.

1968 History of the Prairie Peninsula. *The Quater-*

nary of Illinois, Special Publication, pp. 78-88. University of Illinois, College of Agriculture, Urbana.

Yarnell, Richard Asa

1964 Aboriginal Relationships between Culture and Plant Life in the Upper Great Lakes Region. *Anthropological Papers, Museum of Anthropology, University of Michigan*, No. 23. Ann Arbor.

Environmental Adaptations: The Otomi Indians of the Mezquital Valley

Gloria Young

Department of Anthropology

University of Arkansas, Fayetteville, Arkansas 72701

There was a trend in anthropology, between 1920 and 1950 to view culture as isolated from the biological aspects of man and the physical nature of the world around him. Most anthropologists followed the lead of Franz Boas who had reacted strongly against the evolutionary and environmental determinists of his day — determinists who held that the Western European race was more advanced because the invigorating climate of Europe caused the race to rise farther along the evolutionary scale. From Boas' time until the late 1950's when Julian Steward put forth his theory of multilineal evolution and Coon, Garn, and Birdsell related inherited anatomical and functional variations in man to selection by the physical, biotic and cultural system, few anthropologists viewed man as part of an ecosystem (Baker 1966: 19). During the last few years, however, anthropologists have become more concerned with man's responses to the environment in which he lives and the effect of these responses upon his culture.

The current view is that each environment offers to human occupation a different set of challenges. Therefore a different set of cultural responses, whether they be technical, social or religious may be expected. In facing the challenges, these responses tend to take the path of greatest efficiency in the utilization of the environment (Sanders 1966: 34). This paper describes the utilization of the environment for the collection and production of food and drink by the Otomi Indians of the Mezquital Valley, Mexico.

During the summers of 1969 and 1970 I spent several weeks engaged in ethnographic fieldwork in the Mezquital, a valley which comprises two million acres of the northwest portion of the state of Hidalgo. Situated to the northeast of Mexico City, it is actually a high, arid plateau lying 5000 feet above sea level, enclosed on the north and east by the Sierra Madre Oriental mountain range, on the south by the Sierra de las Cruces and the Valley of Mexico (in which lies Mexico City), and on the west by the Rio Moctezuma (Mendoza 1950-51; 473). Although a small portion of the southern part of the Valley has long been well-watered by natural flows from the higher (6000-7000 feet) Valley of Mexico, the bulk of the Mezquital is extremely dry with several small rivers such as the Rio Actopan and the Rio Tula failing to implement measurably the less than 12 inches total annual rainfall.

The city of Ixmiquilpan, 150 miles northeast of Mexico City on Federal Highway 85, is the heart of the arid northeastern section of the Mezquital. Situated on the Rio Tula, it is an oasis compared to the dry countryside. On the irrigated land close to the city, trees and flowering bushes border fields of alfalfa and vegetables. Most of the inhabitants of the irrigated zone are "Mexicans" and mestizos as opposed to Otomies. Around 85,000 Otomi inhabitants of the Mezquital live in small farming communities outside the irrigated zone. Here cacti and brushy xerophytic plants dot a hilly landscape, white with dust and cut by *barancas*, the deep, dry stream beds

which occasionally carry the runoff water from the escarpment of the Sierra Madre Oriental at the foot of which this portion of the valley lies.

Mesquite trees, after which the Valley is named, and thornless willow-like trees called *pirules* are the only real trees away from the river banks. The abundant cacti, agaves and yuccas often resemble trees, sometimes growing to a height of 10 to 12 feet. These xerophytes include Joshua trees (*palmas*), an agave called *maguey*, several varieties of large prickly pears (*nopal*), an agave resembling sisal called *lechuguilla*, barrel cactus (*biznagas*) and other cacti including *garambullo*, *choconoxtle* and *candeleria*. The hillsides are covered with white and light-colored rocks and the valleys are floored with deep alluvial soil which has washed down the *barancas* and is close to neutral in acidity-alkalinity (pH) (Coleman 1969: 63).

The fauna of the area includes jackrabbits, cottontail rabbits, ground squirrels, a few deer, rats, mice, skunks, opossums, lizards, and prairie rattlesnakes as well as golden eagles, black vultures, redtailed hawks, turtle doves, mourning doves, quail and roadrunners. Toads and insects abound, especially flies, grasshoppers and scorpions (Coleman 1969: 63).

Although the Mezquital teems with plant and animal life, the lack of water away from the few small rivers presents a major challenge to human occupation. Just how long the Otomies have lived in the more arid portions of the Valley is unknown. It is probable that early hunters and gatherers roamed the river banks and that later permanent agricultural villages were established along the rivers. Then, sometime well before the coming of the Spaniards, the Otomies dispersed out into the arid hinterland. This move would have been impossible had not the Otomies had the knowledge of the production of *pulque* from the sap of the *maguey* plant.

Pulque is still today virtually the only drink available to some communities. It is also the major source of vitamin B in the Otomi diet. One man may consume several gallons of *pulque* in a day, so large quantities must be produced to fill the needs of a typical household made up of an extended patrilocal kin group (6 to 15 people). Every family owns the rights to the produce of a number of *maguey* plants, either on their own land or someone else's. At least one plant is ready to be tapped at all times. After from 7 to 11 years growth, the *maguey* plant will put out a stalk which often grows as high as 20 feet with blossoms on top. Just before this event occurs, the Otomies remove the heart from the plant. This is done by cutting some leaves out of the plant and cutting the spines from others to gain access to the center of the plant. The cavity from which the heart is removed is enlarged and scraped with a curved metal tool (*raspa*) to form a bowl. This cavity will fill with from 1 to 3 gallons of sap for as many as 90 days in the larger plants. The person in the family whose chore it is to gather the *agua miel* (as the sap is called)

merely has to carry a large pottery jar to the plant every day and fill it with the sap. This is done by sucking the sap into a capsule-shaped gourd which has a hole in each end. Stopping the top hole with a finger, the gatherer can transfer the *agua miel* to the jar. When the jar is full, the gourd is used as a stopper in the jar mouth. The cavity of the plant is scraped again to induce a new flow and several leaves are folded over the opening and secured by means of the leaves' sharp points so the insects and animals cannot drink the *agua miel*.

At this stage the *agua miel* is almost pure glucose. In this form, before it is fermented, it is fed to babies and to people who are ill. To ferment the sap to make *pulque* a small portion of starter consisting of some already fermented *pulque* is added to the jar of *agua miel* and fermentation takes place overnight. The alcoholic content of *pulque* is low, said to be less than 3%. *Pulque* is sweet and palatable if stored in a cool place; if allowed to become too warm it quickly turns to vinegar. Sometimes *pulque* is used to dampen corn flour to make tortillas or tamales. Oral history states that *pulque* was used to make the mortar for the construction of at least one church because of the lack of water.

Maguey plants are found both wild and domesticated. Cuttings are set out near homes and fields for the sake of convenience, but wild plants are also tapped. Several other wild plants contribute to the Otomi diet. The berries of the *choconoxtle* and *garambullo* cacti are eaten as well as the larger fruit, called *tunas*, of the various prickly-pears (*nopal*). The *tunas* of the small wild *nopales* are red or yellow and taste somewhat like plums. Those of the larger *nopales*, which are often found domesticated, have white flesh and taste much like pears. The pads from both kinds of *nopales* are eaten, often chopped with meat in a stew (*caldo*). Several types of greens, varieties of amaranth called *quelite*, have traditionally added greenery to the Otomi diet. When food is scarce the beans of the mesquite tree may be eaten raw or roasted, although they are most commonly used as food for livestock.

In the villages observed, wild animals are just as important to the diet of the Otomies as wild plants. Almost every family owns a percussion can rifle. The men and older boys hunt cottontail rabbits, jackrabbits, ground squirrels, dove, quail, roadrunners and large edible lizards. The meat is always chopped and made into a stew with red or green chili sauce. Although the Otomies of the area have domesticated animals — a few sheep and goats, some turkeys and chickens, and perhaps a pig — none of these animals are killed for food, except on the special occasion of a wedding or funeral when a chicken may be cooked or a goat barbecued. The domestic animals have been said, rather, to form a faunal bank account. They are used almost exclusively to sell for cash which is then used to purchase items of food not able to be gathered or raised by the family.

Besides these animals themselves, eggs and wool are taken to the weekly market at Ixmiquilpan and sold for cash.

Thus, the Otomies of the Mezquital still hunt and gather as many kinds of foodstuff from the environment as possible. But the type of environment in which they live has shaped the means by which they raise food plants as well. The portion of the Mezquital with which this paper is concerned lies at the base of the Sierra Madre Oriental. Many highland fingers jut out from the escarpment into the valley below. The Spanish term for this piedmont area, *faldas* (skirts), is a good descriptive term. Between the fingers (the fringe of the skirts) lie small fertile valleys which are actually flat alluvial fans created at the mouths of the *barancas* down which the rushing waters of the rainy season (principally June and July) bring soil eroded from the sides of the mountains. The water coming down the *barancas* soaks into the ground when it reaches the valleys, so that the stream bed which runs down the center of each small valley seldom has water in it even during the rainy season. The soil, a brown silt as much as 200 feet deep with few rocks except those in the stream bed, becomes dampened by the underground water flows. The family fields, called *milpas*, lie in the small valleys; the homesteads are on the rocky cactus-covered sides of the fingers above the small valley.

The floor of each small valley is divided into square plots belonging to separate families. After the revolution of 1910 the Otomi farmers were allotted 5 hectares (each hectare contains 10,000 square meters) for each head of a household. These 5-hectare allotments have been subdivided by inheritance by sons until few men in the observed communities own more than a hectare today. The men of a patrilineal kin group hold inherited *milpas* adjacent to one another. The *milpas* of separate extended families may be said to be separated by "edible fences". Besides mesquite trees, the sweet beans of which may be eaten, the fences are made of *nopales*, *maguey* plants and occasional peach, fig, mango, avocado or pomegranate trees. Squash and gourd vines are planted along the fence and often beehives are set nearby. The family *milpa* inside the large fence is subdivided by smaller fences of *magueyes* and fruit trees into the individual land holdings of each adult male of the extended family.

In July after the rains have come, all of the members of a family go to the *milpa* to plow. Two oxen, owned by the family or rented for the occasion, are yoked together by means of a beam lashed to their horns. A tow chain connects this yoke to the clevis of a wooden plow having an iron moldboard and plowshare. Plowing is difficult work, usually requiring two people to hold the handle of the plow and keep the plowshare underground. The oxen are apt to be quite unpredictable and there is generally much hilarity as the men of the family (and women, if they are needed) attempt to plow a straight furrow and turn the oxen at the end of each row.

After the ground has been broken and plowed into rows, corn and beans are planted. Some men prefer to make a hole in the ground with a metal digging stick for the seeds, others simply drop the seeds on the ground and kick a little dirt over them. Seed corn and beans are planted alternately in the furrow, not on top of the row. In this manner they are able to take full advantage of any water which might stand in the furrows after a rain. When the corn is a foot or two high, usually in about two months depending upon how much rain there is, the oxen are again brought to the *milpa* and the plow is run between the rows of plants. The earth is plowed from what was the top of the row into what was the furrow. In other words, the field is reversed and the young corn and bean plants now stand on the tops of the rows. This process not only eliminates weeds between the rows, but places extra dirt over the roots of the plants, providing a better shield against the drying out of the soil around the roots.

By August the rains are over and for four more months the corn and bean plants grow slowly in the constant sunlight, their roots growing deeper to reach the receding moisture. Crops mature in December — six months after planting. The whole family—men, women and children—helps pick and store the corn and beans which have already dried in the field. Most families in the observed villages use all that they grow so that there is no surplus and none of the crops are sold. The cobs and stalks of the corn are fed to the livestock; the bean plants are later plowed under.

In February, although no rain reaches the valley, water comes down the *barancas* from rainfall high in the mountains. Wheat (*trigo*) and broad beans (*habas*) are planted for livestock feed and, if enough water comes down for the crops to survive, are harvested in April. Winter crops are very often lost because of the lack of water.

Most of the protein in the Otomi diet comes from the consumption of beans, meat being eaten only when a hunter is successful or on festive occasions. It might be noted, however, that several kind of grubs (*gusanos*) which are high in protein are eaten by the Otomies. The favorites are large white *gusanos* found in the *maguey* plants, which taste like walnuts when roasted, and smaller *gusanos* eaten with the ears of corn in which they are found, either boiled or roasted.

Thus it can be seen that all parts of the environment are exploited by the Otomies to the extent of their technical ability in order to provide the family with adequate food and drink. Every centimeter of the fertile valley floor is covered with edible plants. The dry hill-sides are combed for game and *tunas*, berries and *quelite* greens when in season. Domesticated animals are fed cornstalks and cobs and mesquite berries. They are then sold to provide money for the purchase of vegetables not able to be raised outside the irrigated zone. The families observed buy tomatoes, onions, garlic, chilis

and coriander to make sauces for the stews or to eat on beans or tortillas. Rice has been bought by the Otomies at the weekly market in Ixmiquilpan for many years and recently some have begun to buy various forms of pasta to prepare with the same sauces. Often the family's supply of corn and beans does not last until the next harvest and additional corn and beans must be bought.

Although the Otomies depend upon the environment for other materials (houses are constructed of stone, organ pipe cactus and maguey provide thatch, and fibers from magueyes and lechugillas are woven into items of clothing, for example), it is in the exploitation of the environment for foodstuff that the greatest amount of time is spent. Much of the day is spent by the family members in collecting, producing and preparing food and drink. Hence this one response to the environment controls the organization of daily life, the division of labor and the routine of the seasons. Ultimately it affects settlement and residence patterns, inheritance rules and the law and judgements concerning land and gathering rights — in short, the entire political arrangement of villages.

Otomi culture, considered apart from the environment in which it operates might be seen as a backwards, tradition-bound culture, stubbornly resisting change.

When viewed as a patterned response to a harsh environment and technical limitations, it appears to be an efficient utilization of the available resources.

REFERENCES CITED

- Baker, Paul T.
1966 "The Application of Ecological Theory to Anthropology." *American Anthropologist*, Vol. 64. Menasha, Wisconsin.
- Coleman, Winfield W.
1969 "The Agriculture of El Dextho, Hidalgo: A Study of Self-supply in a Mexican Village." In *Los Otomies*, edited by H. Russell Bernard. Washington State University, Pullman.
- Mendoza, Vicente T.
1950-1951 "Musica Indigena Otomi: Investigacion Musical en el Valle de Mezquital (1936)." *Revista de Estudios Musicales (Mendoza, Argentina)*, Nr 5/6.
- Sanders, William T.
1966 "Cultural Ecology of Nuclear Mesoamerica." *American Anthropologist*, Vol. 64. Menasha, Wisconsin.

Historical Archaeology In Arkansas

Patrick E. Martin

Arkansas Archeological Survey

Coordinating Office, University of Arkansas Museum

Fayetteville, Arkansas 72701

Any discussion of historical archaeology today must begin with a treatment of the definition of the term "historical archaeology" and of the scope of the problems and goals of this field. A detailed discussion of this sort is beyond the range of the present paper and is dealt with at length elsewhere (Dollar 1969; Jelks 1968; Schuyler 1970; South 1967, 1968; Walker 1968), so I hope to present merely a brief outline of the definition, problems, and goals of historical archaeology and to introduce you to some of the work that is presently being done in Arkansas.

Historical archaeology has "come of age" in this country only in the last few years and as such has not yet built up a comprehensive and generally accepted body of method and theory. In general, however, we can say

that historical archaeology is a combination of the excavation techniques of field archaeology with some of the theoretical methods and assumptions of anthropology and history in order to present a thorough interpretation of sites occupied during the historic period. This is to say that we, ideally at least, not only retrieve information from the ground in the form of artifacts and features, but also use historical documents to identify these artifacts and features and use the theoretical background of anthropology to relate our findings to broader areas of social interaction, such as the evolution of technology, trade, and settlement patterns. These sorts of activities can be used to achieve a wide variety of ends, among them guidance for restoration, reconstruction, or furnishing of significant historic structures, added insights

for written history, and location and identification of sites of known historical significance, such as buildings associated with prominent persons or events. Of primary importance, however, is the contribution that each collection of data makes to the general pool of knowledge concerning man and that each interpretation makes toward the goal of a comprehensive statement about aspects of human behavior.

Arkansas is a state rich in historic background because of its important geographical position in terms of the process of westward expansion and because of its rich natural resources. Some work on historic sites in Arkansas has been done in the past, notably National Park Service excavations at the First Fort Smith and at Arkansas Post, and work done by William Westbury of the Arkansas Archeological Survey on the U.S. Fur Factory trading sites at Spadra on the Arkansas River and the Blanton Estate on the Red River. These excavations and interpretations have provided important backgrounds for all future work in this area by giving direct evidence to supplement the documentary accounts of life in the early history of Arkansas. Presently the Arkansas Archeological Survey is embarking on a project of further excavation at Arkansas Post, and I am involved in research concerning a pottery-manufacturing site in Washington County. It is with the progress and potentials of these two investigations that I will deal in this report.

In February of this year it was brought to my attention that the University had a collection of stoneware sherds from the surface of a site at Cane Hill, southwest of Fayetteville. Some of this pottery was marked "J. D. Wilbur, Boonsboro, Ark.", Boonsboro being one of the other names of the once-bustling community of Cane Hill. The name Boonsboro was in use during the period from about 1860-1880; therefore I've assumed that the Wilbur pottery was produced there during this period.

After some inquiry I found that a number of the local citizens knew where the pottery site was and I was led to it by one landowner, Mr. Clay Pyeatte. The kiln itself is still standing and is in a good state of preservation, thanks to the efforts of Mr. Pyeatte and his family. As yet I have done only a surface collection and some preliminary documentary research, but this site is definitely of some importance, and, as such, deserves further attention. The kiln appears to be of a type common in this country in the eighteenth and nineteenth centuries known as a "ground hog" kiln, which derives from an English kiln tradition and takes its name from the use of earth piled on the sides to insulate the kiln and to buttress the arch. The kiln sits at the edge of a gully through which flows a spring-fed stream offering a year-round water supply. On the slope of this gully is the waster dump, or the dump for broken and misfired pieces. The deposit of waster sherds is thick in this area, and it was here that most of the surface collection was picked up. Also in evidence are parts of the foundation of the structure that served as the work area for this small industry.

It is obvious from the surface collection that the Wilbur pottery was producing a wide variety of utilitarian wares ranging from large crocks to flower pots, jugs to milk pans, and drain tiles to butter churns. A solid program of excavation and analysis should also give important insights into the variety of wares and forms produced, the methods of manufacture and firing, and the importance of the potter's role in the frontier community.

The other historic site project in progress in Arkansas is the upcoming excavation of one or more early Federal period structures at Arkansas Post National Memorial. This now dead town on the lower Arkansas River was once an important center for trade and governmental functions. The primary structure with which we hope to deal, Montgomery's Tavern, was built sometime before 1809 and functioned as a trading factory and tavern for some years. In February of 1820 the Territorial Legislature met in the tavern, and it served as a center for social and civic activities. As it is an important structure of the period, the National Park Service is interested in having excavations conducted to locate and identify it, and to provide data that will help to fill out the picture of its functions and importance to the town and the area.

During the last week of March, a group of students and faculty from the University of Arkansas went to Arkansas Post to conduct preliminary excavations to explore the area proposed as the tavern site and the site for this summer's excavations. A series of trenches was laid out and excavated in order to determine what remained of roads, property lines, and structures in this area. Our search for a road that should bound this property on the north was thwarted by the high spring water table, but almost at once we struck the remains of a brick structure in the lot where the tavern is believed to have stood. Here again, the water table prevented complete excavation, but we were able to determine that this was a small brick structure of some sort that collapsed into a subsurface excavation, and was subsequently filled in with domestic trash, including broken ceramics, glass, bones, and iron objects. Further excavation this summer should allow us to identify this structure.

In another trench we found two large postmolds, containing brick rubble and charred wood, that could prove to be part of a fence line at the edge of a lot. Elsewhere, we cut into what appears to be a deposit of domestic trash that may date to the earlier French occupation of this area. Included was a fragment of a marked Dutch clay pipe of a type that was commonly used and traded in the last half of the eighteenth century. Also in this area were fragments of wine bottles, French gunflints, and other domestic refuse.

Though we've only just scratched the surface on both the Wilbur pottery and Montgomery's Tavern, the results are encouraging in both projects, and hopefully these investigations will provide information which will further illuminate Arkansas' historic past and add to the growing body of knowledge concerning human behavior.

BIBLIOGRAPHY

- Dollar, Clyde D.
1969 More Thoughts on Theory and Method in Historical Archaeology. In *Conference on Historic Site Archaeology Papers*, Vol. 4, Part I, pp 83 - 94. University of South Carolina Press, Columbia.
- Jelks, Edward B.
1968 Observations on the Scope of Historical Archaeology. In *Historical Archaeology*, Vol. II, pp. 1-3. Moravian College, Bethlehem.
- Schuyler, Robert L.
1970 Historical and Historic Sites Archaeology as Anthropology: Basic Definitions and Relationships. In *Historical Archaeology*, Vol. IV, pp. 83-89. Moravian College, Bethlehem.
- South, Stanley A.
1968 What Archaeology Can Do To Expand Historical Research. In *Conference on Historic Site Archaeology Paper*, Vol. 3, Part I, pp. 50-57. University of South Carolina Press, Columbia.
- South, Stanley A.
1967 Historical Archaeology Forum. In *Conference on Historic Site Archaeology Papers*, Vol. 2, Part 2. University of South Carolina Press, Columbia.

The Demonstration, and A Suggested Immune Role, of Mouse Antibodies Against Salmonella enteritidis Endotoxins

Jimmie D. Barrack, and Leo J. Paulissen

Department of Botany and Bacteriology

University of Arkansas

Fayetteville, Arkansas 72701

Mouse immunity or resistance to *Salmonella enteritidis* infection is a complex mosaic of many facets. This report is concerned with that aspect which involves mouse reaction to the endotoxins of the bacteria.

It is a generally held view that protective antibodies against infections by the Gram-negative enteric bacteria, *Salmonella*, are those specific for the Vi, when present, and O (endotoxin) antigens. Antibodies formed against the H (flagellar) antigens are held to be non-protective. Although these views specifically relate to clinical salmonellosis in man, classically typhoid fever, the same is reported for chimpanzees (20) and, by implication, thus would seem to apply to other mammals. Inoculation of mice with *S. enteritidis* was, therefore, expected to result in the development of protective antibodies against the O antigens of the organism (Vi is absent). However, when agglutination tests were conducted with sera from

immunized NAMRU mice, titers were either non-existent or very low (14, 15) compared to titers of 1:320 or more in human typhoid fever. Lockhart and Paulissen (9), therefore, performed agglutination tests under varying conditions to improve the test sensitivity. They found titers up to 1:320 against the H antigens but still only to 1:40 against the O antigens in the mouse antisera. The phenomenon is not peculiar to this strain of mice. Hobson (7) reported agglutinin titers of up to 1:80 in an unidentified strain of mice immunized with *Salmonella typhimurium*. Morello et al (10) were able to detect O agglutinin titers to 1:320 in pooled sera from CD-1 mice hyperimmunized against *S. typhimurium* but, in a group of five individual mice infected with the organism, one had a titer of 1:80 while the rest had 1:40 or less. Hashimoto et al (6) reported that ddN strain mice produced O agglutinin titers of 1:160 one month following immunization with *S. enteritidis*.

Jimmie D. Barrack and Leo J. Paulissen

Despite these comparatively low titers, mice do develop protective serum factors of some sort following immunization with *Salmonella* organisms. This was shown by Lockhart and Paulissen (9) who reported that survival time of mice in experimental salmonellosis was extended from 1.6 days to 13.6 days when the animals were passively immunized with mouse antisera before being challenged. Also, Lieberman et al (8) reported that serum from a mouse injected with a *S. enteritidis*-paraffin oil-adjuvant mixture gave passive protection to 50% of challenged mice when inoculated with 0.01 ml./ mouse antiserum.

These several observations led to the speculation that either O agglutinins were unimportant in mouse immunity to *Salmonella*, or that, simply, they were not being adequately measured, i.e. a more sensitive test for them was needed. Actually, O agglutinins may be unimportant. Hobson (7) for example, concluded from his work that the anti-O antibody of mice against *S. typhimurium* was of doubtful benefit. Also, Gorer and Schutze (5) could not correlate anti-O agglutinins in mice with resistance to *S. enteritidis*. Still, it seemed to us that the agglutinins, even of low titer, should not be considered lightly. Their very presence in mouse sera after exposure to the bacteria seemed to implicate them in some sort of functional role in immunity. Thus we decided to try to develop a more sensitive test for mouse serum antibodies. One method for enhancing the sensitivity of an agglutination test is to coat erythrocytes with bacterial antigens (3). After a number of trials, a successful procedure was developed by which agglutination of sheep cells coated with *S. enteritidis* endotoxin was accomplished, and a high titer of mouse "agglutinins" was demonstrated.

The endotoxins of *Salmonella* also have pharmacological effects on the mammalian hosts. Among various organs and tissues, they involve the liver which appears to have a major role in their detoxification as well as in clearance of toxic bacteria from the blood (1, 17). With the demonstration of endotoxin antibodies it was decided to see if mouse antisera in some way mediated the effects of the bacterial endotoxins of the animal. It was found that an increase in the respiration of liver tissue occurred in animals given large numbers of bacteria (endotoxin). This increase, however, was considerably lessened when mouse antisera were employed in counteracting the stimulatory effects.

MATERIALS AND METHODS

Experimental Animals: Ten-to-sixteen week old NAMRU (4) mice were used throughout this work. The animals were housed in one-gallon glass jars and supplied Purina Laboratory Chow and water *ad libitum*. A six-to-eight week old rabbit housed in a standard wire cage was used to obtain serum for use as a control. Commercial rabbit food (Farmer's CO-OP) and water were supplied *ad libitum*.

Test Organism: *Salmonella enteritidis* (I, IX, XII . . . g,

m) was obtained from the culture collection of the Department of Botany and Bacteriology, University of Arkansas and was originally identified as number 64 of the Agricultural Experimental Station of the University of Kentucky (14). The culture was maintained lyophilized on beads in individual ampoules in order to minimize virulence, or other, changes. When cultures were required, the beads were plated directly upon tryptose agar or heart infusion agar plates and held 24 hours at 37 C. **Vaccine:** The heat-killed vaccine was prepared essentially as described heretofore (14), and contained approximately 2.2×10^9 bacteria/ml.

Mouse antisera: Each mouse received three intraperitoneal injections of 0.2 ml vaccine on alternate days. Fifteen-to-sixteen days following the final injections, the mice were sacrificed and exsanguinated by severing major blood vessels in the thoracic cavity. The pooled blood was collected in sterile tubes, held at room temperature two hours, ringed with a wooden splint and refrigerated overnight. The serum was removed with a capillary pipette the following day and stored in screw-capped tubes at approximately -20 C. Non-immunized mice were employed to collect normal serum.

Rabbit antiserum: Two days before starting the immunization of the rabbit, it was bled for the collection of the normal control serum. The rabbit received six injections of vaccine on alternate days as follows: (1) 0.5 ml subcutaneously, (2) 1.0 ml intraperitoneally, (3) 2.0 ml intraperitoneally, (4) 3.0 ml intraperitoneally, (5) 5.0 ml intraperitoneally and (6) 0.2 ml intravenously. The serum was collected 14 days after last injection and was processed and preserved by the same procedure used for mouse sera above.

Tube agglutination tests: Standard procedures were used in tube agglutination tests to detect and measure agglutinin titers in rabbit and mouse antisera, using saline as a diluent.

Endotoxin preparation: After three unsuccessful methods, one suggested by Oakley (13) and Thomas (19), a second after Neter et al. (12) a third after Ribi et al, (16) were tried, a fourth was found to work. It was essentially the same as the third mentioned but with an additional step of heating as suggested by Neter et al. (12). The procedure is as follows: Several Roux bottles containing 50 ml heart infusion agar were inoculated with 2 ml each of a 24-hour culture of *S. enteritidis* in heart infusion broth. After incubation, 20 ml cold sterile saline were added to each bottle for harvesting the organisms. The cell suspension was washed three times in sterile saline, diluted to a net reading of 770 on the Klett-Summerson colorimeter with a no. 54 filter, and cooled to 6-12 C. Two volumes of pre-cooled diethyl ether were added to the cell suspension contained in a separatory funnel and shaken gently for six consecutive ten second intervals. The bacteria were left overnight in the funnel at 6-12 C. The aqueous phase was drawn off, and an equal volume of ether added, shaken and allowed to

stand overnight as before. The aqueous phase was again drawn off and residual ether was removed by bubbling air through the remaining material. The organisms were removed by centrifugation at 3800 rpm for 70 minutes and then discarded. The supernatant was dialyzed five days in daily changes of distilled water at 4-5 C. Sodium chloride was added to a concentration of 0.85%. The endotoxin was precipitated by the addition of cold absolute ethanol to a total volume of 68%. It was added slowly with continuous stirring and the suspension was allowed to stand overnight. The precipitate was collected by centrifugation at 4000 rpm for 70 minutes, the supernatant discarded and the precipitate dissolved in distilled water. This was transferred to a dialysis bag and dialysis against water was continued 36 hours in the cold, reprecipitated and collected as before. The precipitate was dissolved in a minimal quantity of distilled water. One-ml portions were pipetted into 10 x 100 mm soft glass tubes and dried under vacuum. The sealed tubes were stored at 4-6 C. When needed for hemagglutination tests, a vial containing endotoxin was dissolved in sterile saline and mixed thoroughly to a total volume of 12.5 ml in a round-bottom flask fitted with a reflux condenser. This was heated to a gentle boil for one hour.

Coated Sheep erythrocytes: Ten ml of defibrinated sheep blood were centrifuged at 2000 rpm for ten minutes after which the liquid part was discarded. The erythrocytes were then resuspended in sterile saline to the original volume. Washing in this manner was done three times. The final washing was carried out at 1000 rpm for 8 mins. after which saline was added to make a 10% suspension of cells which was stored at 4-6 C until use. Coating of the cells after Fulthorpe (3), was accomplished by incubating them with an equal volume of the endotoxin preparation for two hours in a 37 C water bath with frequent shaking. They were then washed 3 times in 12 ml saline to remove free or unabsorbed endotoxin and finally saline was added to make a 10% suspension. Two drops (0.033 ml) of this sensitized erythrocyte suspension were added to each tube containing the serum dilutions from a 19 gauge needle which delivers 60 drops per ml. The cells were evenly distributed by shaking, incubated 30 minutes in a 37 C water bath and stored overnight at 4-6 C.

Preparation of liver slices: For respiration studies mouse liver slices were processed as follows: The mice were injected intravenously with 0.2 ml containing approximately 2.2×10^9 heat-killed bacteria. To facilitate the injection, the mouse's tail was held 3-4 min. in a beaker of warm water. The controls received 0.2 ml saline. Thirty minutes afterward all mice were sacrificed by cervical dislocation, the livers were excised and placed in petri plates filled with chilled Krebs-Ringer phosphate solution pH 7.4. The lobes of each liver were separated and the gall bladder was removed and discarded. The liver was sliced with a pre-cooled Stadia-Riggs microtome which produced slices 0.5 mm in thickness. Each slice

was maintained in ice-cold Krebs-Ringer phosphate solution, pH 7.4, until just prior to gassing the Warburg flasks at which time it was placed in a flask.

Measurement of respiratory rates: Carbon dioxide production by liver slices was determined by the direct method with the Warburg respirometer. The Warburg flasks were charged with 2.5 ml of Krebs-Ringer phosphate solution, pH 7.4, in the main chamber, 0.5 ml of 0.1 M glucose in Krebs-Ringer phosphate solution in the side-arm and in the center well either 0.2 ml 20% sodium hydroxide for carbon dioxide absorption or 0.2 ml distilled water to preclude carbon dioxide absorption. Liver slices from each mouse were placed in the main compartments of duplicate flasks. All flasks were gassed five minutes with 100% oxygen before being placed on the 37 C water bath of the Warburg. Five minutes were allowed for temperature equilibration before closing the respirometer and taking readings resulting from endogenous respiration. These continued for ten minutes until zero times when the substrate was tipped into the main compartment. The tests were allowed to continue one hour with readings made at 15 minute intervals. A dry-weight determination of each slice was made after rinsing with distilled water, drying at 50 C for 24 hours and storing in a desiccator for 8-12 hours.

RESULTS AND DISCUSSION

The initial experiments in this work were undertaken to substantiate the development of only low titers of bacterial agglutinins in mice against *S. enteritidis*. We immunized mice with *S. enteritidis* according to a schedule known to produce immunity (14). A rabbit was also immunized in order to obtain antiserum which would be used to check the serological test procedures. In Table I are found results which show that agglutinins were indeed found to be wanting in mouse antisera, but reached a titer of 1:2560 in the rabbit antiserum. We proceeded to attempt the more sensitive test. Methods have been developed whereby soluble antigens, like endotoxins, are absorbed onto relatively large particles like charcoal, alumina, or erythrocytes, so that when mixed with specific antisera an "agglutination" of the particles takes place. Because the particles are large, a readily visible reaction occurs. Our first attempt at performing this kind of test was unsuccessful. The culture filtrate was used as suggested by Oakley (13) and Thomas (19) but did not produce the desired results because the preparation hemolyzed the cells. A second method of endotoxin preparation by Neter et al. (12) also failed to work. In Table I it can be seen, using this method, that although the rabbit antiserum titer was enhanced from 1:2560 to 1:5120, no "agglutinins" were demonstrated in the antisera of mice. The third method after Ribi et al. (16) involving extraction of the endotoxin with aqueous ether also did not work in that no hemagglutinating antibodies were demonstrated in the mouse sera but, furthermore, the antibody titer of the rabbit serum was also not detectable (Table I). Since heating has been

Jimmie D. Barrack and Leo J. Paulissen

reported to help in hemagglutination tests (12) we heated our endotoxin to 100 C for 1 hour. When the endotoxin, prepared by the method of Ribí, et al. (16) was heated before coating the sheep erythrocytes, titers of hemagglutinins of 1:1280 for mouse antisera and 1:40960 for the rabbit antiserum were obtained (Table I). Thus it is seen that mice do develop antibodies against the *S. enteritidis* endotoxin and can be measured by this test. The test proved to be sixteen times more sensitive than the bacterial agglutination test; an "increase" in titer of the rabbit serum from 1:2560 to 1:40960. Fulthorpe (3) found the hemagglutination test to be about eight times more sensitive than the bacterial agglutination tests, also using rabbit antisera. Both Neter et al. (11) and Morello et al. (10), however, found the bacterial agglutination test titers equal to the hemagglutinin titers using coated erythrocytes.

Since antibodies to *S. enteritidis* endotoxins were found in the mouse, it was wondered if they had any protective value. It is known that both clearance of bacteria from the blood and the endotoxin action by bacteria implicates the liver of mammals (1, 17). One approach to determine liver involvement is to test the tissue for increased respiration as a reaction to the toxin. This was suggested by the work of Woods, et al. (21) who observed a slight elevation, above the control level, in the respiratory rates of tissues from mice previously injected intravenously with a sublethal dose (20 ug) of *Serratia marcescens* endotoxin. In our initial trials, liver slices were taken from mice fasted six hours before sacrifice but they showed essentially no change when exposed to the bacteria. When mice were fasted 24 hours, however, the liver tissues were found to show increased respiration to a ratio of 3.17:1 in one experiment and to 2.44:1 in a repeat experiment (Table II). This measurable stimulation provided a basis for testing whether

antibodies to *S. enteritidis* may moderate the liver's response. This was done in two ways. By the first procedure, mice were passively immunized with 0.1 ml. mouse antisera against *S. enteritidis* 12 hours before being inoculated with the bacteria (endotoxin). The liver tissues were removed 30 minutes later. The ratio of respiration was found to be 1.39:1 (Table II). By the second method, the bacteria were incubated 30 min. at 37 C with 1:15 dilution of the mouse antisera before injection into the mice, the ratio of respiration of liver slices became 1.58:1. In both cases, then, the stimulation of respiration was considerably modified. If it is assumed that such a modifying influence ameliorates the taxing effect of the toxin on the animal, it can be construed as beneficial to the mice in dealing with the toxin action. The mechanism seems to be related less to possible antiserum action on the liver than to the modification of the toxin by the antibodies in a way that increased respiration of the liver slices did not occur. This seems all the more likely when it was seen that bacteria, incubated with antisera before injection, also failed to stimulate liver slices. Just what role antibodies play in an animal's resistance to endotoxin is not exactly known (18). Freedman (2) showed that tolerance to endotoxin can be passively transferred in plasma or serum from animals conditioned to be endotoxin-tolerant by repeated endotoxin injections. This suggests an antibody role but when he mixed the plasma with endotoxin before injection together, protection was not obtained, thus raising the question whether an antibody was involved. In the present work, mixture of the antisera with the bacteria (endotoxin) before injection "reduced" liver stimulation just as passive inoculation with antisera before injection of the bacteria. Here it seems an antibody is involved and suggests it has some kind of neutralizing effect on the endotoxin so that the liver's respiration is not elevated.

Table I

Demonstration of Mouse and Rabbit Serum Antibodies Against *Salmonella enteritidis* (Reciprocals of Titers)

Experimental Animals	Immunized With Heat-Killed <i>S. enteritidis</i>	Standard Bacterial Tube Agglutination Tests	Hemagglutination Tests Using Sheep Red Blood Cells Coated With <i>S. enteritidis</i> Endotoxin (Fulthorpe's Method) Extracted From Bacteria By:		
			Heating The Bacteria In Saline At 100C One Hour	Aqueous Ether	Aqueous Ether And Heating 100C One Hour
Mice	Yes	0	0	0	1 280
Mice	No	0	0	0	0
Rabbit	Yes	2 560	5 120	0	40 960
Rabbit	No	0	0	0	0

Table II

Modifying Effects of Mouse Antisera Upon Stimulation
of Liver Tissue Respiration by *Salmonella enteritidis*
Administered After 24 Hours Fasting

Experiment No.	Pretreatment	Q_{CO_2} Values (μ CO ₂ /mg Dry Wt. Liver/Hour in 100% O ₂ Atmosphere) of Liver Slices Obtained From Mice 30 Min. After Inoculation With:		Q_{CO_2} Ratio Between Bacteria-Inoculated And Saline-Inoculated (Control) Mice
		2.2 x 10 ⁸ Heat-Killed <i>S. enteritidis</i> in 0.2 ml. Saline	Saline — 0.2 ml.	
I	None	8.46	2.67	3.17:1
II	None	2.29	0.94	2.44:1
III	Mice Were Given 0.1 ml. Mouse Antisera l. p. 12 Hours Before Inoculation	2.16	1.55	1.39:1
IV	Before Inoculation, Bacterial Suspension Was Incubated 30 Min. At 37°C In An Equal Volume Of 1:5 Dilution Of Mouse Antisera	3.28	1.07	1.58:1

REFERENCES

1. Farrar, W. Edmund, Jr. and Corwin, Laurence M. 1966. The essential role of the liver in detoxification of endotoxin. *Ann. N. Y. Acad. Sci.* 133:668-684.
2. Freedman, Henry H. 1960. Reticuloendothelial system and passive transfer of endotoxin tolerance. *Ann. N. Y. Acad. Sci.* 88:99-106.
3. Fulthorpe, A. J. 1954. Agglutination of sheep erythrocytes sensitised with *Salmonella* polysaccharides. *J. Pathol. Bacteriol.* 68:315-325.
4. Garber, E. D. and Hauth, F. C. 1950. A new mutation with asymmetrical expression in the mouse. *J. Hered.* 41:122-124.
5. Gorer, E. F. and Schutze, H. 1938. Genetical studies on immunity in mice. II. Correlation between antibody formation and resistance. *J. Hyg.* 38:647-662.
6. Hashimoto, H., Honda, T., Kawakami, M. and Mitsuhashi, S. 1961. Studies on the experimental Salmonellosis. VI. Long-lasting immunity of mouse immunized with live vaccine of *Salmonella enteritidis*. *Jap. J. Exp. Med.* 31:187-190.
7. Hobson, Derek. 1957. Chronic bacterial carriage in survivors of experimental mouse typhoid. *J. Pathol. Bacteriol.* 73:399-410.
8. Lieberman, Rose; Douglas, John O. A. and Mantel, Nathan. 1960. Production in mice of ascitic fluid containing antibodies induced by *Staphylococcus*- or *Salmonella*-adjuvant mixtures. *J. Immunol.* 84:514-529.
9. Lockhart, Jack and Paulissen, Leo J. 1966. Enhanced phagocytosis of *Salmonella enteritidis* with hypoagglutinating mouse antisera. *Ark. Acad. Sci. Proc.* 20:85-94.
10. Morello, Josephine A., Digenio, Teresa A. and Baker, Edgar E. 1964. Evaluation of serological and cultural methods for the diagnosis of chronic Salmonellosis in mice. *J. Bacteriol.* 88:1277-1282.
11. Neter, Erwin; Bertram, Lee F., Zak, Dorothy A., Murdock, Miriam R. and Arbesman, Carl E. 1952. Studies on hemagglutination and hemolysis by *Escherichia coli* antisera. *J. Exp. Med.* 96:1-15.
12. Neter, E., Westphal, O., Luderitz, O. and Gorzynski, E. A. 1956. The bacterial hemagglutination test for the demonstration of antibodies to Enterobacteriaceae. *Ann. N. Y. Acad. Sci.* 66:141-156.
13. Oakley, C. L. 1954. Bacterial toxins. Demonstration of antigenic components in bacterial filtrates. *Annu. Rev. Microbiol.* 8:411-428.
14. Paulissen, L. J. and Shechmeister, I. L. 1958. The effect of sublethal whole-body x-radiation on active immunity. *J. Infec. Dis.* 103:188-195.
15. Ralston, James R. and Paulissen, Leo J. 1964. Motility inhibition: A new quantitative test for anti-*Salmonella enteritidis* activity in antisera of mice. *Bacteriol. Proc.* p. 69.
16. Ribi, Edgar; Milner, Kelsey C. and Perrine, Theodore D. 1959. Endotoxic and antigenic fractions from the cell wall of *Salmonella enteritidis*. Methods for separation and some biologic activities. *J. Immunol.* 82:75-84.
17. Skarnes, Robert C. 1970. Host defense against bacterial endotoxemia: mechanism in normal animals. *J. Exp. Med.* 132:300-316.
18. Stetson, Chandler A., Jr. 1961. Symposium on bacterial endotoxins. IV. Immunological aspects of the host reactions to endotoxins. *Bacteriol. Rev.* 25:457-458.
19. Thomas, Lewis. 1954. The physiological disturbances produced by endotoxins. *Annu. Rev. Physiol.* 16:467-490.
20. Tully, J. G., Gaines, S. and Tibertt, W. D. 1963. Studies on infection and immunity in experimental typhoid fever. IV. The role of H antigen in protection. *J. Infec. Dis.* 112:118-124.
21. Woods, Mark W., Landy, Maurice; Whitby, James L. and Burk, Dean. 1961. Symposium on bacterial endotoxins. III. Metabolic effects of endotoxins on mammalian cells. *Bacteriol. Rev.* 25:447-456.

Notes on the Algae of Arkansas. 1. *Chrysococcus*, *Kephyrion*, *Kephyriopsis*, *Pseudokephyrion* and *Stenokalyx*

Richard L. Meyer

Department of Botany and Bacteriology

University of Arkansas

Fayetteville, Arkansas 72701

ABSTRACT

The genera *Chrysococcus*, *Kephyrion*, *Pseudokephyrion* and *Stenokalyx* have received some consideration by investigators in Europe and in the boreal forest and tundra-range regions of the United States. Many of the species are considered to be cold-water stenotherms, thus occurring more frequently in northern habitats. In the present paper 4 species of *Chrysococcus*, 4 species of *Kephyrion*, 2 species of *Pseudokephyrion* and 2 species of *Stenokalyx* from Arkansas are discussed.

INTRODUCTION

The genera *Chrysococcus*, *Keyhyrion*, *Kephyriopsis*, *Pseudokephyrion* and *Stenokalyx* have received considerable attention by European investigators. In the new world these genera have been reported only by a few workers. The earliest records for the United States were from Ohio (Lackey, 1938), more recently from Alaska (Hilliard, 1966, 1967) and Minnesota (Meyer and Brook, 1969). These genera are usually considered to be cold-water stenotherms thus favoring more northern habitats. A review of the sites in which the organisms have been collected suggests that they would most frequently be found in humic, brown water ponds and lakes having a pH ranging from circum-neutral to acid (7.6-4.5). The species presented in this report have been previously listed by Meyer (1970) and Meyer, et al (1971) from Arkansas from a moderately eutrophic lake, Lake Fayetteville.

METHODS

Plankton samples were obtained by No. 28 plankton net hauls or Kemmerer water bottle from Lake Fayetteville, Washington County. Living material was examined when possible or collections were treated with M₃ fixative (Meyer, 1971). Drawings and photographs were made with the aid of a Zeiss Photoscope II.

ACKNOWLEDGEMENTS

The work upon which this paper is based was supported in part with funds provided by the Office of Water Resources Research, U.S. Department of Interior, under Grant Number A-011-Ark, as authorized under the Water Resources Act of 1964, P. L. 88-379 as amended by P. L. 89-404.

DISCUSSION

The genera discussed here have been the subject of much controversy. The taxonomic problems will be solved after a considerable number of organisms have been analyzed and/or cultures are established. Bourrelly (1957) places emphasis on a number of flagella while Fott (1959) utilizes lorica structure in order to distinguish these genera. Lund (1960) and Hilliard (1967) have further discussed the complex relationship of the genera *Kephyrion*, *Kephyriopsis*, *Pseudokephyrion* and *Stenokalyx*. This paper will utilize the more stable features of lorica morphology for distinguishing the genera. Morphogenesis of the lorica, protoplast structure, asexual and sexual reproduction will be considered in latter studies.

Chrysococcus is recognized by a *Chromulina*-type cell surrounded by a lorica. The flagellum extends through a minute aperture in the lorica. The remaining genera each have a large opening through which the flagellum extends. The cell type is incompletely known, thus these genera are distinguished from one another by lorica morphology. In *Kephyrion* the lorica is of uniform thickness and without helical undulations or ridges. *Kephyriopsis* is distinguished from the others by the transverse, thickened, mesh bands separated by thinner zones. *Pseudokephyrion* loricas are marked by helical undulations or grooves and those of *Stenokalyx* by transverse ridges. Representatives of each of the genera are known from Lake Fayetteville.

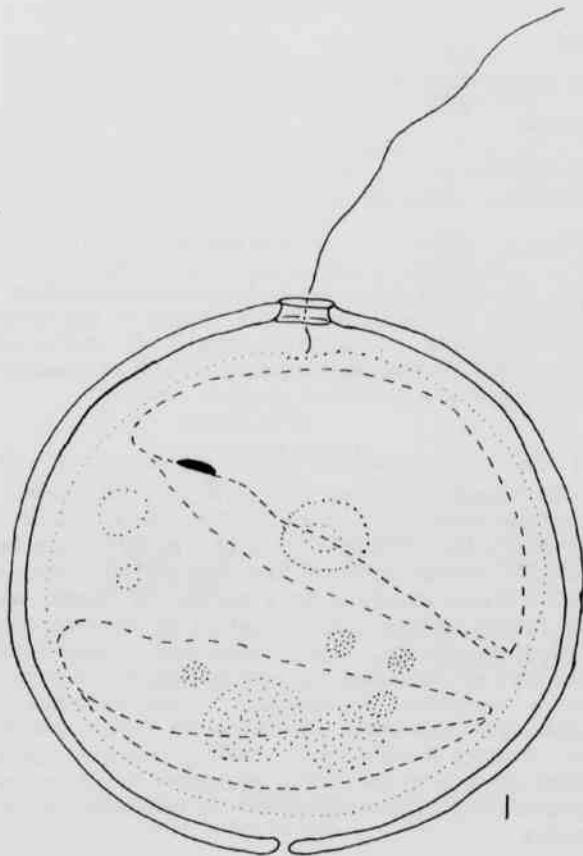
CHRYSOCOCCUS KLEBS 1892

The cells characteristic of the genus *Chrysococcus* are of the *Chromulina*-type with a single flagellum extending a small aperture in the lorica. The cytoplasm

contains one or two parietal, golden-brown plastids, sometimes a stigma and often two contractile vacuoles.

Chrysococcus minutus (Fritsch) Nygaard, 1932

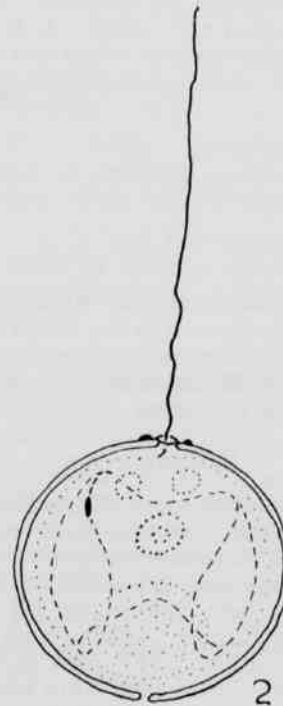
Chrysococcus diaphanus Skuja, 1950*



The smooth thin lorica is spherical, 14-18 μ diameter, sometimes a transparent yellow or hyaline. The lorica is biporate with an annulus around the apical aperture. The antapical aperture is a simple perforation. The protoplast contains two chromatophores. The chromatophores position are variable; often one will be found at the cell apex. Two contractile vacuoles lie at the equator of the cell. Several chrysolaminarin and fat droplets are scattered throughout the cytoplasm. Cell diameter is 12-16 μ and the flagellum length is approximately equal to the cell diameter.

Four biporate species and one variety of *Chrysococcus* are known — *C. minutus*, *C. biporus*, *C. porifer*, *C. diaphanus* and *C. rufescens* var. *biporus*. *Chrysococcus diaphanus* can be distinguished from these species by the variable position of the chromatophores, usually perpendicular to the cell axis, and the medial placement of the contractile vacuoles.

*On all Figures 1.5 inches = 10 microus.



The lorica is spherical or ellipsoidal, 6 to 8.5 μ diameter, with two diametrically opposed apertures. The flagellar pore is marked by one or two small papillae. The lorica color varies from yellow to dark red-brown.

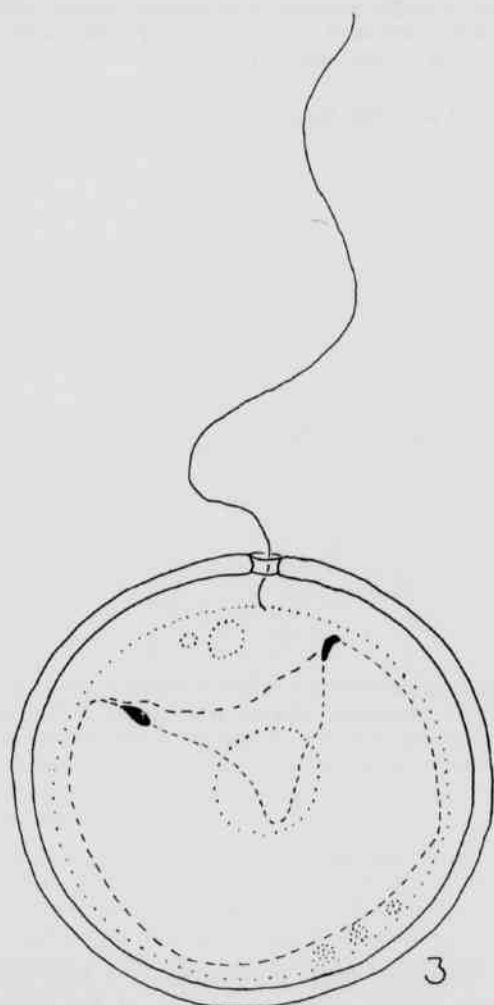
The protoplast completely fills the lorica and contains a single large golden-brown chromatophore with a stigma in the margin. Astigmatate cells have also been observed in collections.

A single large chrysolaminarin droplet occupies the antapical region of the cell while two contractile vacuoles occur at the apical pole. The flagellum is approximately $1\frac{1}{2}$ to 2 times the cells diameter.

This biporate species can readily be recognized by its small size.

Bourrelly (1957) described a new variety based on the presence or absence of the stigma. The mixture of typical and atypical cells within the same population and the disregard of this organelle as a characteristic feature in other organisms suggest that it is of dubious taxonomic value. Bourrelly's *C. minutus* var. *astigmata* Bourrelly (1957) is considered as synonymous with the original species.

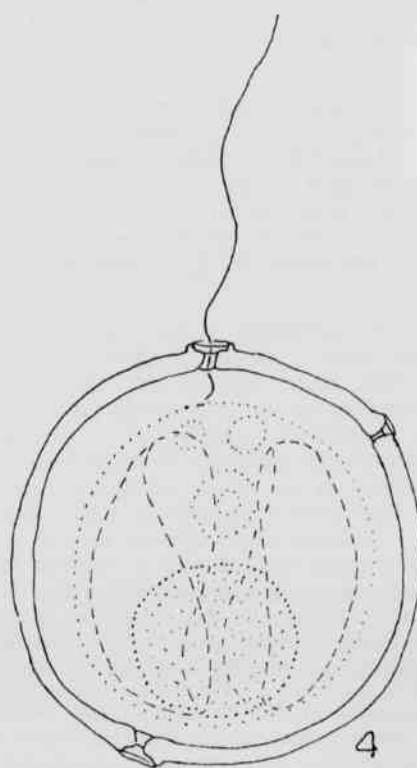
Chrysococcus rufescens Klebs 1892



The smooth hyaline to dark brown lorica contains a single aperture and has a diameter of 8-12 μ . The biporate, triporate and compressed forms have been reported from other locales but the spherical form is found in most collections from Arkansas. The loricas are infrequently broadly elliptical.

The cup-shaped chromatophore encompasses most of the protoplast. A stigma may be present as the apical margin of one or both the chromatophores. As in *C. minutus* cells without stigmas have been observed in populations with one or more stigmas per cell. One or two contractile vacuoles linear the insertion of the flagellum. Several lipid droplets may be present in the antapical region. The flagellum is 2 to 2½ times the cell diameter.

Chrysococcus triporus Matrienko, 1951



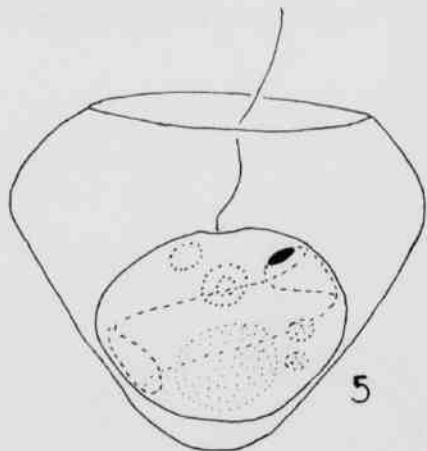
Lorica varying from spherical to ovoid, with three annulate pores. The placement of the pores is irregular, usually with two adjacent. The spherical lorica's are 6.5 to 8 μ diameter and the oval forms are 7-9 μ long and 6-7 μ wide. Color of the loricas varies from yellow-brown through red-brown to dark-brown.

The protoplast contains two disc-shaped chromatophores. The chromatophores are usually lateral but may be in a posterior position. In the posterior position they encompass the chrysolaminarin vacuole. No stigma was observed. The two contractile vacuoles are near the insertion of the flagellum.

This species is similar in morphology to *C. rufescens* var. *tripora* Lund (1942). They, however, differ size, position of plastids, stigma, and reserve products. Until further study the two taxa will be considered as separate entities.

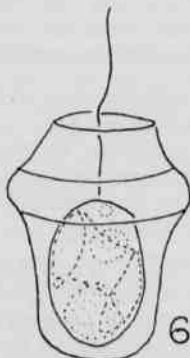
KEPHYRION Pascher, 1911

Lorica, vase-shaped, without undulations, grooves, ridges or flanges, maybe campanulate or laterally inflated.

Kephyrion cupuliforme Conrad, 1930

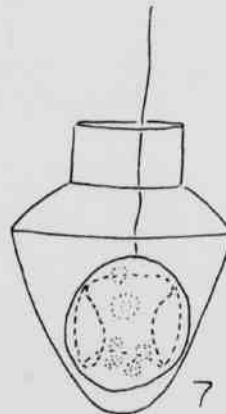
Lorica is broadly conical with a rounded base with a slightly infolded upper margin. The lorica is 9-10 μ long by 11-12 μ broad and the aperture is 8-9 μ diameter. The lorica is thin without any markings but is frequently pale yellow to golden brown in color.

The protoplast in our specimens was ovoid with a single band-shaped chromatophore. The stigma occurred on the upper margin; when present. A chrysolaminarin vacuole and lipid droplets lie in the posterior portion of the protoplast. A single flagellum, about the same length as the protoplast, was observed.

Kephyrion rubi-claustri Conrad 1939

The dark reddish brown lorica is cylindrical in profile with an inflated ring slightly above the equator. The cell diameter at the ring is 5 μ , whereas the main body is only 3-4 μ diameter and attains a length of 5-7 μ . The aperture approximates the body diameter.

A ellipsoidal to ovoid protoplast occupies the basal portion of the lorica. The small protoplast (4 x 2 μ) contains a single parietal band-shaped plastid and posterior chrysolaminarin droplet. A single flagellum extend through the lorica aperture.

Kephyroin schmidii Bourrelly, 1957

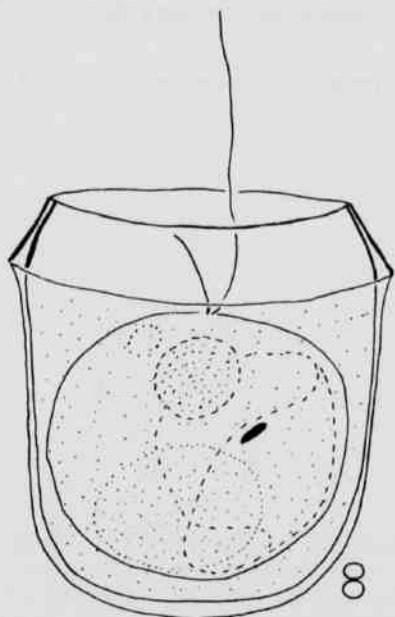
A cylindrical collar is attached to a lenticular dome covering conical posterior portion of the lorica. The lorica is 8-9 x 6 μ , the collar length and aperture diameter are more approximately the same dimension, 3 μ . The lorica lacks thickened regions or other markings and is yellow to brown in color.

The protoplast is spherical to obovoid (3-5 μ) with a single parietal plastid and flagellum.

KEPHYRIOPSIS Pascher et Ruttner, 1913

The lorica of *Kephyriopsis* is distinguished from all other genera by transverse thickened bands. In some instances a mesh-work is visible but in our material the bands are incrustated with minerals and differentially pigmented. The bands are reddish-brown to dark brown while the intermediate zone are hyaline to golden brown.

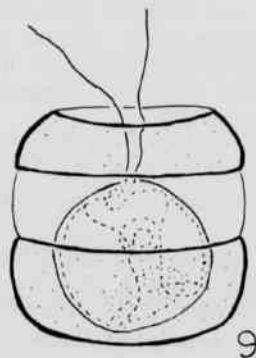
***Kephyriopsis ovum* Pascher et Ruttner, 1913**



The lorica is slightly ovoid, slightly longer than broad (11-12 x 9.5-10 μ) and basally truncated. The lower portion of the lorica covered by reddish brown incrustations. Infrequently a mesh-work is visible under the incrusting layer. The upper margin is without the mesh-work or deposits.

The protoplast usually occupies the basal half of the lorica. It may be adjacent to the lorica or free without visible means of attachment. The cell contains a single golden brown disc-shaped chromatophore; with and without a stigma. The nucleus and single contractile vacuole are located at the protoplast apex. In certain specimens two flagella were visible but frequently only the longer could be seen.

***Kephyriopsis cincta* Schiller, 1926**



The cylindrical lorical is nearly equal length and width (6-7 μ). The lorica is encompassed by anterior and posterior thickened bands. The bands are incrustated with a reddish substance and the intercalary zone is golden-brown.

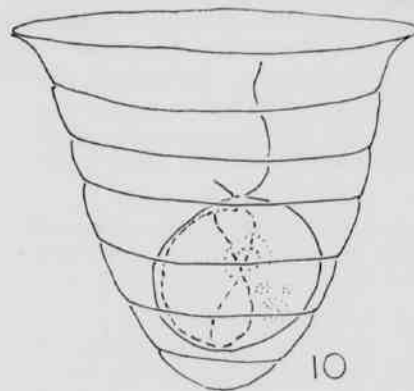
The spherical protoplast appears to be free from the lorica as no attaching organelle was visible. It contains a single band-shaped chromatophore fills the small protoplast (4 μ dia.). A single long flagellum was always visible (2x) but in certain cells the second flagellum was observed. When present the second flagellum was approximately 1-1½ times the protoplasts diameter.

Skuja (1956) depicts *Kephyrion littorale* with two differentially thickened bands. These bands are not found in either the English (Lund, 1942) or Alaska (Hilliard, 1967) specimens. Skuja observed only a single flagellum in the Swedish collections and thus included placed them in the genus *Kephyrion*. Our observations concerning the variability in number of flagella agree with Fott's (1959) conclusion that their number is not a reliable generic characteristic.

PSEUDOKEPHYRION Pascher, 1913

Helical undulation or grooves provide *Pseudokephyrion* with a distinctive morphology. The helix may vary from a flat pitch with several gyres to a steep pitch with only 2 or 3 gyres.

***Pseudokephyrion pilidum* Schiller, 1929**

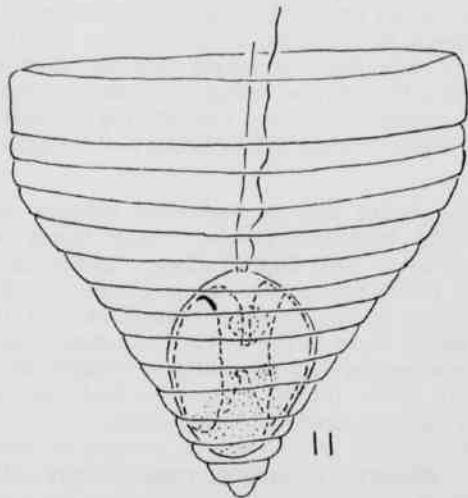


The thimble shape lorica is 10-12 μ wide and 11-12 μ long with 6-7 gyres or rings. The rim is slightly flared and the base rounded. Pigmentation varies of light yellow to ochre.

The protoplast is a small sphere (4-5 μ dia.) in the base of the lorica. A single disc-shaped plastid occupies one side. No stigma or contractile vacuole was visible. The long flagellum (1½x) did not extend beyond the

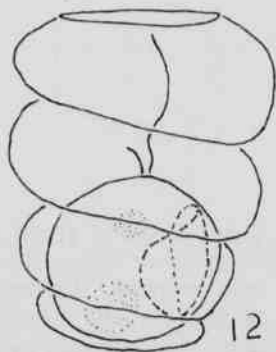
Richard L. Meyer

lorica mouth. A second smaller flagellum ($\frac{1}{4}$ - $\frac{1}{2}x$) could be seen in some specimens when the cells were properly oriented.

Pseudokephyron schilleri Conrad, 1939

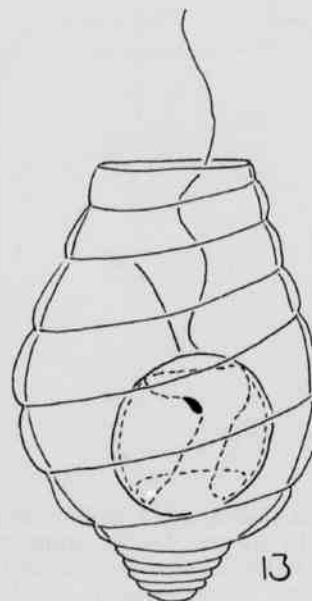
Lorica conical, sides straight or slightly concave ending in a small knob and encircled by 10-12 ridges. The length and maximum diameter are nearly equal (10-12 μ). The aperture margin is straight or slightly rounded. Color varies from hyaline to ochre.

Two subequal flagella are inserted at the protoplast apex and extend beyond the lorica. One bilobed chromatophore encompasses the equator. A small stigma may be present. Chrysolaminarin and lipid vacuoles are found in the cell posterior. Protoplasts are elliptical to ovoid in form (5.5-6 x 4-5 μ).

Pseudokephyron spirale Schmid, 1934

The yellow colored lorica is cylindrical (8-9 x 7 μ) with 3-4 well-defined sinistral gyres.

A small ochromonoid cell (5 μ dia.) is appressed to the floor of the lorica. A single small disc chromatophore and chrysolaminarin vacuole were visible.

Pseudokephyron undulitissimum Scherffel, 1927

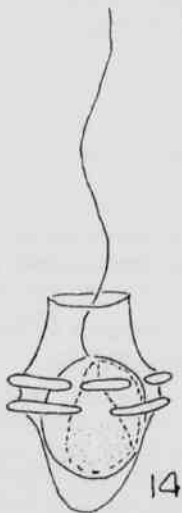
The dimensions of the lorica, 10-12 x 6.5-8 μ with an aperture of 3-4 μ , is similar to the type. The lorica has an elliptical form with 6-8 slightly oblique gyres. A small knob with 3-4 gyres is attached posteriorly. Typically the lorica is yellow-brown, however dark brown specimens have been collected.

The protoplast morphology varies from a small sphere (5-6 μ dia.) to a large fusiform cell. The latter usually develops just prior to cell division. A single parietal chromatophore, with stigma, occupies most of the smaller protoplasts. Both uni- and biflagellated specimens have been observed. Flagella are 1-2 and $\frac{1}{2}$ -1 time the body length.

STENOKALYX Schiller 1926

Stenokalyx is unique and easily identified by the ridges or flange circumscribing the lorica. All species have a **Chromulina** type protoplast.

Stenokalyx inconstans Schmid, 1934



Lorica ovoid, with two ranks of interrupted flanges around the equator, slightly tapering toward the apices. Length 6-8 μ and width variable 4.5-7 μ with an aperture of 3.5 μ . The flanges and dark reddish brown in contrast by the lorica body.

The protoplast (4-6 μ dia.) contains a single parietal idcs-like plastid, basal chrysolaminarin droplet, and contractile vacuole. The apical flagellum is 2-2½ times the protoplast diameter.

Stenokalyx laticollis Conrad, 1939



Lorica thin, dark golden brown, rounded base with parallel sides, (6-7 x 4.5 μ). Two rows of discontinuous ridges circumscribe the cylindrical lorica slightly above and below the equator. These are more widely spaced than those of *S. inconstans*.

Protoplast spherical, apparently free from the lorica. Similar in appearance to *S. inconstans* except slightly smaller (3-3.5 μ dia.).

LITERATURE CITED

- Bourelly, P., 1957
Recherches sur les Chrysophycees.
Rev. Algol., Mem. No. 1:1-412.
- Fott, B., 1959
Zur Frage der Sexualitat bei den Chryso-
monaden. Nov. Hedw. 1(1):115-129.
- Hilliard, D. K., 1966
Studies on Chrysophyceae from some Ponds
and Lakes in Alaska. V. Notes on the Oc-
currence of Uhytoplankton in an Alaska pond.
Hydrobiol. 28:553-576.
- _____, 1967
Studies on Chrysophyceae from some Ponds
and Lakes in Alaska. VII. Notes on the gen-
era *Kephyrion*, *Kephyriopsis* and *Pseudokephyrion*.
Nov. Hedw. 14(1): 39-56.
- Lackey, P. B., 1938
Scioto River forms of *Chrysococcus*.
Amer. Midl. Nat. 20:619-623.
- Lund, J. W. F., 1942
Contributions to our knowledge of British Al-
gae. New Phytol. 41(4):274-292.
- _____, 1960
New or Rare British Chrysophyceae. 3. New
Records and Observations on Sexuality and
Classification. New Phytol. 59(4):349-360.
- Meyer, R. L., 1970
The Freshwater Algae of Arkansas. I. Intro-
duction and Recent Additions. Ark. Acad. Sci.
Proc. 23:145-156, 1969.
- _____, 1971
Development and Distribution of Phytoplankton
Regimes in a South Central Reservoir.
Symp. Man-made Lakes; Nat. Acad. Sci. (in
press).
- _____, and A. J. Brook, 1969
Freshwater Algae from the Itasca State Park,
Minnesota. II. Chrysophyceae and Xanthophy-
ceae. Nov. Hedw. 17(½):105-112.
- _____, J. H. Wheeler and J. R. Brewer, 1971
Freshwater Algae of Arkansas. II. New Ad-
ditions Ark. Acad. Sci., Proc 24, 1970 (in
press).
- Skuja, H., 1956
Taxonomische und biologische Studien über
das Phytoplankton Schwedischer Binnenge-
wasser. Nov. Act. Soc. Sci. Ups., Sen. 4 16-
(3):1-404.

A Facility For The Biological Treatment Of A Complex Chlorophenolic Waste

(Preliminary Report)

William F. Evans, Division of Life Sciences
University of Arkansas at Little Rock, Little Rock, Arkansas 72204

ABSTRACT

The City of Jacksonville, Arkansas, is attempting to determine if aeration of a combined domestic sewage — chlorophenolic herbicide waste prior to release into conventional waste stabilization lagoons will be useful in the microbiological oxidation of chlorophenols and chlorophenoxy acids.

Discussion

Industrial waste entering the Jacksonville, Arkansas sewage treatment facility arises from the manufacture of the hormone-type herbicides 2,4-dichlorophenoxy acetic acid (2,4-D) and 2,4,5-trichlorophenoxy acetic acid (2,4,5-T). The waste consists principally of a mixture of chlorophenols and chlorophenoxy acids, and is chemically adjusted to approximately pH 7.0 prior to release from the manufacturing plant.

Consulting engineers concluded that a mechanized aeration basin or lagoon might be useful in the biological degradation of the chlorophenolic portion of the total waste complex. Such an aeration basin was subsequently constructed, and located so as to permit aerating the total flow of the system prior to release into the two existing 22-acre waste stabilization (oxidation) lagoons. With this method, wastes could be aerated before transfer to the stabilization lagoons, and (hopefully) hydraulic and organic overloading of the stabilization lagoons could be avoided. The assumption that this treatment method would promote the bacterial degradation of the chlorophenolic industrial waste was based upon published (1,2,3,6) and private communications (4,5).

The aeration lagoon and its relationship to the original sewage treatment plant and stabilization lagoons is shown in Fig. 1. The aeration lagoon has a 3 to 4 day detention time for an average flow of 2.5 MGD. The lagoon measures 213 ft. by 768 ft., and has a capacity of 8.4 MG at an operating depth of 11.5 ft. The aeration equipment consists of four floating type units positioned in tandem in the long dimension of the lagoon. Each aeration unit consists of a rotating element, 8 feet in overall diameter, made up of 32 cupped steel blades, powered by a 75 HP electric motor. Each unit is supported by a circular, fiberglass, doughnut-type raft, anchored to the lagoon levees by means of cables. Water picked up by the blades of the units is broken up into many sheets and droplets, serving to effect transfer of oxygen to the water at varying rates subject to temperature, atmospheric pressure, and degree of saturation of the water with oxygen. The oxygenation capacity of each aerator can be varied from a minimum of 166 pounds per hour to a maximum of 249 pounds per hour by changing the depth of flotation, and hence that of blade

immersion. This is accomplished by the addition of water to (or removal from) each pontoon.

It was agreed that biological, chemical, and hydraulic data should be collected before the aeration system was installed, and these data compared with data obtained during a twelve-month period immediately following completion of the aeration system. The biological study included investigations of the factors that influence the removal of chlorophenolics by the biological system of the treatment plant, and a study of the organisms in various parts of the treatment system and receiving waters. The chemical study included the choice of suitable methods for the identification and determina-

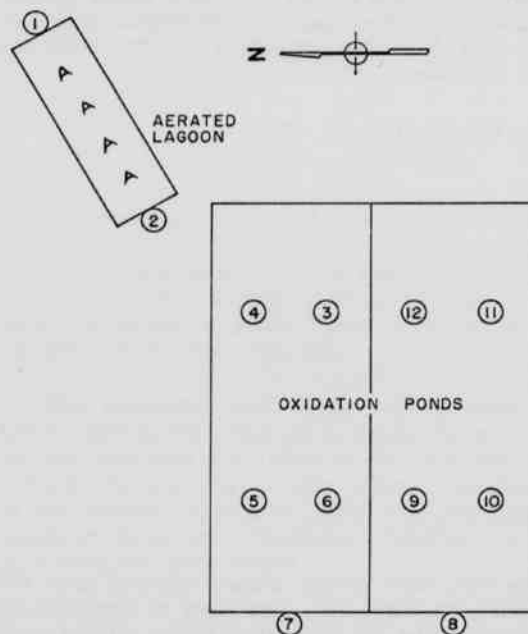


FIG. 1

BIOLOGICAL STUDY
SAMPLING POINT LOCATIONS

tion of the chlorophenolics encountered and, where feasible, to apply the methods to determine the relative rates of biochemical degradation. The hydraulic study was to obtain necessary quantity and quality data of the various wastes flowing into the sewage treatment plant including the effluent of the industrial plant and the waste waters within the plant, to permit better evaluation of the project. The overall project study was to permit evaluation of the feasibility and performance of the joint treatment of herbicidal-domestic waters, and pollution abatement of receiving waters as a result of this treatment. Since the biological study was carried out by the writer, this paper will be concerned primarily with that aspect of the project.

PROCEDURES

Time Period Covered

A preliminary biological survey was carried out during the summer of 1968, prior to construction of the aeration system. Following completion of the system, biological sampling and analyses were carried out during the period of June 6, 1969 until June 29, 1970. Approximately 100 samplings at each of 12 sampling points were made during this time, which included four seasonal intensive sampling periods of two weeks each, during which samples were taken at all sampling points each day. At other times weekly samples were taken at all twelve points.

Sampling Procedure

The aeration lagoon was sampled at the influent and effluent on each sampling day. Five samples were taken at each oxidation lagoon during each sampling day: four at grid points, and one at each effluent (Fig. 1). Water and air temperature, pH, and dissolved oxygen values were determined at all sampling points at the time of sampling. All samples were analyzed for total and fecal coliform bacteria and for plankton organisms. Intermittent bottom sampling produced virtually no benthic organisms.

Analytical Methods

Plankton. Plankters were identified and counted by means of a Sedgwick-Rafter all-glass counting chamber. Most plankton samples were of such a density as to require no concentration; but those which did require it were concentrated by passing the water sample through a membrane filter of pore size $0.45\ \mu$. Total chamber counts were made, and the appropriate concentration factors applied whenever necessary in order to determine the number of organisms per liter.

Coliform Organisms. Total coliform counts were obtained by the familiar membrane filter procedure. Three filtrations of each sample (0.1, 1.0, and 10.0 ml) were made, and the average number of coliform organisms per 100 ml water sample obtained by noting the number of colonies exhibiting a "golden sheen" that grew during

each incubation, converting this to numbers per 100 ml, and then averaging the counts for the three dilutions.

Counts of fecal coliform organisms were obtained in a manner similar to that employed for total coliforms, with notable exceptions. Difco mFC BROTH BASE was used, and the medium rehydrated by suspending in distilled water and adding 1% rosolic acid solution according to the directions of the manufacturer of the medium. Membrane filters through which water samples had been passed were encased in small water tight petri dishes and incubation carried out by submerging the dishes in the inverted position in a water bath maintained at a temperature of $44.5^{\circ}\text{C} \pm 0.5^{\circ}\text{C}$ for 24 hours. Dark blue colonies are indicative of fecal coliform organisms, and averages per 100 ml were obtained as in the method for enumerating total coliform bacteria.

pH. Determination of pH was made immediately upon sampling by employing a Hach Model 1975 battery-operated pH meter, calibrated frequently by means of standard buffer solutions.

Dissolved Oxygen. Dissolved oxygen in parts per million and water and air temperatures in degrees centigrade were obtained as soon as each sample was taken, by means of a Model 54 Oxygen Meter (battery operated), manufactured by the Yellow Springs Instrument Company. The meter was calibrated periodically against the Winkler method for the determination of dissolved oxygen.

Conclusions

Data accumulated during the preliminary survey and during the twelve-month period of sampling following completion of the aeration system have not yet been released for publication by the Arkansas Pollution Control Commission and the City of Jacksonville; therefore, no firm conclusions as to the efficiency of the treatment method under discussion can be presented at this time. However, the following general statements can be made:

1. Removal of chlorophenols by the aerated lagoon alone ranged from 55 to 89%, while the overall removal of chlorophenols by both the aerated lagoon and stabilization ponds ranged from 87 to 94%.

2. Removal of chlorophenoxy acids was less than that of chlorophenols, ranging from approximately 30 to 70% within the lagoon and 49 to 80% by the lagoon and oxidation ponds.

3. During plant operation, the average BOD_5 was 15 mg/l; chlorophenols, 0.1 mg/l; and chlorophenoxy acids, 1.1 mg/l.

4. There appeared to be no significant change in pH or dissolved oxygen values or in types or numbers of plankton organisms one year after operation of the aerated lagoon was instigated.

William F. Evans

5. The reduction in numbers of coliform organisms is quite good at the stabilization lagoon effluents, the picture of coliform density adhering quite closely to what one would expect in a "normal" system, exhibiting high summer counts, low winter counts, and intermediate spring and fall counts.

References

1. Mills, R. E., "Development of Design Criteria for Biological Treatment of an Industrial Effluent Containing 2,4-D Waste Water," Report of 14th Industrial Waste Conference, Purdue University, Lafayette, Indiana, pp 340-358 (1959).
2. Faust, S. D., and Aly, O. M., "Studies on the Removal of 2,4-D and 2,4-DCP From Surface Waters," Report of 18th Industrial Waste Conference, Purdue University, Lafayette, Indiana, pp 6-8 (1963).
3. Ingols, R. S., Gaffney, P. E., and Stevenson, P. C., "Biological Activity of Halophenols," Journal Water Pollution Control Federation, pp 629-635, April 1966.

4. "Waste Water Study for Hercules Powder Company, Jacksonville, Arkansas Plant," conducted by Department of Environmental Science, Rutgers University, Brunswick, New Jersey, September 6, 1963.
5. A. W. Bush, Consulting Engineer, Houston, Texas, "A Study of Chemical and Biological Oxidation of a 2,4-D Waste Water," September 1963, report prepared for Hercules Powder Company.
6. Geldreich, Edwin E., Clark, Harold F., Huff, Clifton B., and Lois C. Best. "Fecal-Coliform-Organism Medium for the Membrane Filter Technique," Journal American Water Works Association, pp 208-214, Feb. 1965.
7. "Special Survey in Upper Bayou Meto Basin — 1967," report of the Arkansas Pollution Control Commission.

Acknowledgement

The supportive funds for this research were granted under the auspices of Federal Water Quality Administration grant WPRD 246-01-68.

Studies of *Arundinaria*: Experimental Induction of Flowering and Additional Observations in the Field

Daniel L. Marsh, Division of Biology
Henderson State College, Arkadelphia, Arkansas 71923

ABSTRACT

Arundinaria has been observed for three successive seasons at a site near Amity, Arkansas. In advance of the 1971 flowering period rhizomes were taken from the field, pruned, and placed either in an environmental chamber or in the greenhouse in water or in sandy soil. Flowering occurred under each condition, but was most rapid and profuse in transplants growing in sandy soil in the greenhouse. Observations point to the possibility of induction of flowering or to the possible existence of an annually flowering race. Possible economic uses are considered.

In my first paper on the flowering of our native bamboo, *Arundinaria gigantea* (Walt.) Muhl., it was pointed out that this event is of infrequent occurrence according to the literature (Marsh 1970). My interest in this phenomenon was stimulated by the account of Fernald and Kinsey (1958, p. 91-2) on the use of the grains as food.

McClure (1966, chapters 2 and 6) has extensively discussed the problems presented by the irregularity in the flowering and fruiting of many of the bamboos. Clayton (1965) stated that although periodicity in bamboos may not differ in principle from that in annual plants, the long cycle involved discourages serious experimental work.

Two well-known botanists of Arkansas, Dr. Delzie Demaree and Dr. Dwight D. Moore have both told me that over the years the flowering of *Arundinaria* has rarely been observed. Dr. Demaree also told me that Dr. E. J. Palmer (deceased) had long sought the flower-

ing plants in the field and considered the occurrence to be quite rare.

Since 1967 I have continued to observe the flowering of cane in widely scattered locations in Arkansas. Attention has been especially directed to a site along the Caddo River north of Amity in Clark County. Heavy flowering was first observed in the Amity site on the south side of the river in the spring of 1969. Floriferous culms died during the summer following flowering.

In the spring of 1970 flowering was observed in the same site and on a later trip, flowering was found in a canebrake on the north side of the river. The presence of old dead culms indicated that flowering had probably occurred on the north side in 1969 also.

Profuse flowering was found again on both sides of the river in 1971. In contrast to the previous two springs, a considerable amount of fruit was observed to form and shed out on the ground. Insect attack was

very heavy, and no germination of the grain has been found in the field.

Transplant Experiments

On February 28, 1971, shoots and rhizomes were found bearing buds up to an inch and a half long. Several rhizomes were dug up and taken to the laboratory. After the shoots and roots were pruned, six rhizomes were planted in sandy soil in the greenhouse, two were placed in vessels of water, and two were planted in a flat which was placed in a Lab-Line Biotronette Mark III environmental chamber.

During the experimental time incoming daylight was the only light source in the greenhouse. Temperatures ranged from 40° to 100°F, and relative humidity ranged from about 15 to 100%.

The environmental chamber was set on an eleven hour light, thirteen hour dark schedule. The temperature was maintained between 80° and 85°F until March 5 and then gradually increased to 90°. Relative humidity fluctuated from 25% to 54% with approximately 40% as the most frequent value.

The Amity site was checked again on March 15 and on April 12. Canebrakes in other localities were also checked while on field trips during the period of the experiments. On April 4 several transplants were taken from the floodplain of Lost Creek west of Sheridan in Grant County. These were planted in the greenhouse.

Results

Of the ten transplants made February 28, eight developed inflorescences. Flowering was rapid, the first occurring in only nine days. Plump succulent grains developed in most spikelets in the greenhouse.

In the transplants taken from Grant County the buds have not yet expanded.

No flowering had taken place in the Amity site by March 15, but on April 12 profuse flowering was observed. Development in the field is at a much earlier stage than in the greenhouse. Flowering has not been observed at other sites thus far in 1971.

Details of the experimental results in the transplants taken from Amity follow.

Transplant 1, sandy soil in greenhouse. This was the first plant to flower, some flowers being open on March 9. Four flowering branches developed from the uppermost node remaining on the main culm. By March 16 a flowering shoot from the base of the plant approximately the height of the rest of the plant. This shoot developed to about twice this height by March 24. By April 13 disarticulation was well underway, and florets were lying on the ground. Grains measured from about 1 to 1.5 cm in length.

Transplant 2, sandy soil in greenhouse. Only a vegetative shoot developed.

Transplant 3, sandy soil in greenhouse. Flowers which were closed on March 10 were open on March 12. Additional flowering shoots had formed and reached a

height of about 46 cm by March 16. Formation of fruit was evident by March 30.

Transplant 4, sandy soil in greenhouse. Flowers which were still closed on March 16 were open by March 24. Setting of fruit followed.

Transplant 5, sandy soil in greenhouse. Shoots had expanded up to 20 cm in length by March 16, but inflorescences were not evident. The flowers did not open until after March 24.

Transplant 6, sandy soil in greenhouse. Flowers were beginning to open on March 16. Flowering was very profuse by March 24, and grain formation was assured by March 30. Fully developed grains were obtained from spikelets on April 13.

Transplants 7 and 8, placed in vessels of water. Development was slower than in some of those growing in soil. One shoot bearing young spikelets had reached a height of 70 cm by March 24. Adventitious roots formed under water were chlorophyllose and bore root hairs along the entire length. Root development was less in the taller of the two plants. Flowers had opened by March 30, and the contrast in root development was still evident. Grain formation was sparse.

Transplants 9 and 10, placed in environmental chamber. One of the plants did not grow. In the other plant the bud of the highest node began elongation by March 8 when the temperature reached 90°. The shoot was 16.5 cm long on March 9, 31 cm long on March 11, 74 cm long and with an expanding inflorescence on March 15. The flat was transferred to the greenhouse on March 16 for photographing and left there. After the anthers exerted the florets dried without grain formation.

Discussion

The results of the experiments seem to preclude the significance of a photoperiod since plants in the environmental chamber and in the greenhouse flowered under different lighting schedules. Likewise drought, a frequently suggested cause of flowering, is ruled out as a factor at least during the period in which the flowering shoots elongate and develop, since even those with the roots growing in vessels of water produced flowering shoots.

Two factors which could be significant are the increase in temperature resulting from transplanting to indoors and the injury stimulus of pruning. Evidence that grazing or other injury may induce flowering cannot be ruled out, but it has not proved to be inevitably reliable. Flowering at the Amity site would not be solely a response to normal seasonal temperature increase unless annual flowering occurs, and flowering does not occur throughout this local population. Injury factors which may be involved include flooding and insect attack as well as grazing.

Of course carefully planned experiments with control

Daniel L. Marsh

plants will be essential to a further investigation of flowering, and an experimental program including controlled temperature and injury as well as continued field investigations is projected from the present time through the following spring.

That some of the observed cane populations of Arkansas could represent unusual gene pools is a possibility which must be considered. Flowering occurs much more regularly in some species of *Arundinaria* than is known in our native *A. gigantea*. McClure (1966, p. 202) has expressed the potential importance of unusual clones of bamboos as follows:

The economic success of large-scale exploitation will depend to an important extent on the cultivation of elite bamboos, selected for outstanding quality and high productivity. Such traits will be found associated only in an occasional individual clone.

Fernald and Kinsey (1958) have discussed the value of both the grain and the young shoots of *Arundinaria* for human consumption, and Gould (1958, p. 5) has pointed out its use as a valuable livestock forage. McClure (1966, p. 147 ff.) has emphasized the need of more comprehensive studies of the bamboos not only for purely scientific purposes but also to select and introduce bamboos for agriculture, domestic industries

(such as pulp for paper-making) and conservation.

The finding either of a reliable way to induce flowering in the native *Arundinaria* or of an annually reproducing race would enhance the possible domestication of this species.

LITERATURE CITED

- Clayton, W. D. 1965. Introduction to Arber's "The Gramineae" in *The Gramineae*; a study of cereal, bamboo, and grass by Agnes Arber, 1965 reprint, *Historiae Naturalis Classica* Vol. 41. J. Cramer, Weinheim. xxxii + 480 pp.
- Fernald, M. A. and A. C. Kinsey. 1958. *Edible Wild Plants of Eastern North America* (Revised by R. C. Rollins). New York and Evanston: Harper & Row, Publishers. xii + 452 pp.
- Gould, F. W. 1968. *Grass Systematics*. New York, etc.: McGraw-Hill Book Company. xi + 382 pp.
- McClure, F. A. 1966. *The Bamboos: a fresh perspective*. Cambridge, Mass.: Harvard University Press. xv + 347 pp.
- Marsh, D. L. 1970. Observations of flowering in *Arundinaria gigantea* (Walt.) Chapm. in Arkansas. Arkansas Academy of Science Proceedings 24: 36-37.

A Survey of the Vascular Flora of Poinsett County, Arkansas

Michael I. Johnson

Department of Biology, Memphis State University, Memphis, Tennessee*

ABSTRACT

A survey of the vascular flora of Poinsett County, Arkansas was made over a period of 13 months. The fifteen field trips taken were planned to include representative soil associations and geographic areas within the county. Three hundred sixty-three species and varieties from eighty-three families were collected or examined.

INTRODUCTION

Poinsett County is located in the northeastern portion of Arkansas within the region designated by Dale (1963) as "Mississippi Alluvial Plains and Terraces". It has an area of 760 square miles of which 81.2% (396,000 acres) (U.S. Dept. of Commerce, Bureau of the Census, 1967) is in farmland. This county is located in the northeastern part of Arkansas, and it is bordered by five other Arkansas counties: Mississippi County on the east; Craighead County on the north; Jackson County on the west; and Cross and Crittenden Counties on the south.

*Rewritten from a thesis submitted to the faculty of the graduate school of Memphis State University in partial fulfillment of the requirements for the Degree Master of Science. Present address 3438 Sophia, Memphis, Tennessee 38118.

Poinsett County has a long growing season, with an average frost-free period of 231 days extending from March 18 to November 4. The average yearly rainfall is 49.94 inches and is usually well distributed throughout the year (U.S. Dept. of Commerce, Environmental Science Service Bureau, 1967-68).

The St. Francis River is a meandering alluvial waterway with a large floodplain (U.S. Dept. of Agriculture, Soil Conservation Service, 1963). It drains Poinsett County east of Crowleys Ridge. West of Crowleys Ridge, the relatively level land is drained by a series of ditches which empties into the L'Anguille River or the Bayou DeView. Several large reservoirs are present to control possible floodwaters.

The lowest point (200 feet) in Poinsett County occurs in the St. Francis flood plain (35°30' North, 90°30' West), while the highest point (440 feet) is located on Crowleys Ridge (35°29' North, 90°42' West).

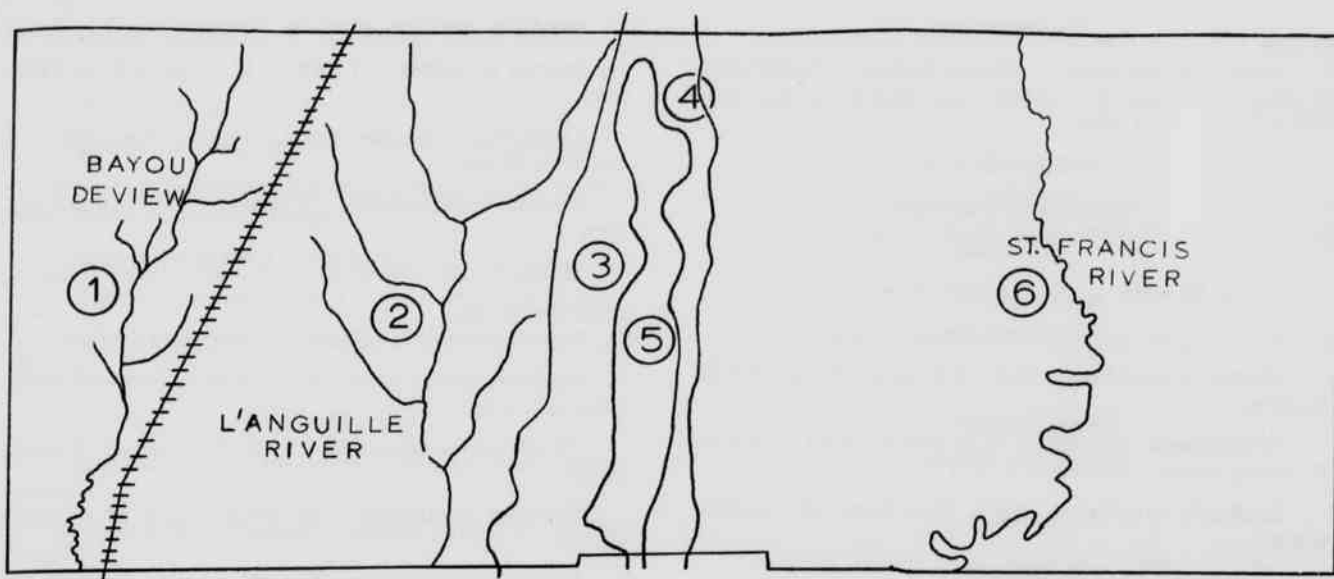


Figure. 1 — Poinsett County Collection Areas

- (1) Bayou DeView Runoff System (2) L'Anguille River Runoff System (3) Crowleys Ridge — West Slope
 (4) Crowleys Ridge — East Slope (5) Crowleys Ridge (6) St. Francis River Floodplain.

SURVEY

Representative sampling stations were selected in the county with respect to soil type, exposure, water availability, altitude and relationship to man's interference. Fifteen field trips were made from September, 1967 through October, 1968. Over 3,000 miles were covered during the trips, but because of the size of the county it was not possible to visit all sampling stations on every trip. In general, trips were made every two weeks during the growing season. Specimens were deposited in the Memphis State University Herbarium, Memphis, Tennessee.

After a species had been found it usually was not collected again. Therefore, distribution of a species within the county is probably more general than indicated. Data on soil association was also noted but is not included in this paper.

The specimens are listed below, including the area of the county in which the collection was made (Fig. 1). Specimens were identified using keys of Duncan (1967); Fernald (1950); Gleason (1952); Gleason and Cronquist (1968); Radford, Ahles, Bell (1964); and Shanks and Sharp (1963). The nomenclature and arrangement of families for this study follows Radford, Ahles, Bell (1964) except in cases of more recent adoption. Genera are arranged alphabetically in each family. Species are also alphabetically arranged within a genus.

ACKNOWLEDGEMENTS

I wish to express appreciation to Dr. Edward T. Browne, Jr. under whose direction this study was made. Special thanks is extended to Dr. Edwin B. Smith of the University of Arkansas for his professional assistance, and to Dr. Edward L. Richards of Arkansas State University for his assistance in the University's herbarium.

PTERIDOPHYTA

Equisetaceae

Equisetum hyemale L. St. Francis River Floodplain.

Aspidiaceae

Cystopteris fragilis (L.) Bernh. Crowleys Ridge.

Polystichum acrostichoides (Michx.) Schott. Crowleys Ridge

Aspleniaceae

Asplenium platyneuron (L.) Oakes. Bayou DeView Runoff System Crowleys Ridge.

SPERMATOPHYTA

GYMNOSPERMAE

Pinaceae

Pinus virginiana Mill. Crowleys Ridge. East Slope of Crowleys Ridge.

Cupressaceae

Juniperus virginiana L. Crowleys Ridge. West Slope of Crowleys Ridge. L'Anguille River Runoff System. East Slope of Crowleys Ridge.

ANGIOSPERMAE

MONOCOTYLEDONEAE

Typhaceae

Typha latifolia L. St. Francis River Floodplain.

Alismataceae

Alisma subcordatum Raf. L'Anguille River Runoff System.

Echinodorus cordifolius (L.) Griseb. East Slope of Crowleys Ridge.

Sagittaria graminea Michx. East Slope of Crowleys Ridge.

Poaceae

Andropogon virginicus L. East Slope of Crowleys Ridge.

**Aristida dichotoma* Michx. Crowleys Ridge.

Aristida oligantha Michx. West Slope of Crowleys Ridge.

Aristida ramosissima Engelm. Crowleys Ridge.

Arundinaria gigantea (Walt.) Muhl. East Slope of Crowleys Ridge.

Bromus racemosus L. St. Francis River Floodplain.

Cynodon dactylon (L.) Pers. East Slope of Crowleys Ridge.

Digitaria ischaemum (Schreb.) Schreb. ex Muhl. Crowleys Ridge.

Echinochloa crusgalli (L.) Beauv. East Slope of Crowleys Ridge.

Echinochloa microstachya (Wieg.) Rybd. East Slope of Crowleys Ridge.

Elymus macounii Vasey. Bayou DeView Runoff System.

Elymus riparius Wieg. L'Anguille River Runoff System. East Slope of Crowleys Ridge.

Elymus virginicus L. St. Francis River Floodplain.

**Elymus virginicus* L. var. *glabriflorus* (Vasey) Bush. L'Anguille River Runoff System.

Erianthus strictus Baldw. L'Anguille River Runoff System.

*Arkansas State University Herbarium Specimen

Hordeum pusillum Nutt. St. Francis River Floodplain.

Leersia oryzoides (L.) Swartz. St. Francis River Floodplain.

Leptochloa filiformis (Lam.) Beauv. West Slope of Crowleys Ridge.

**Lolium temulentum* L. L'Anguille River Runoff System.

Muhlenbergia schreberi J. F. Gmel. West Slope of Crowleys Ridge.

Oryza sativa L. L'Anguille River Runoff System.

Panicum anceps Michx. East Slope of Crowleys Ridge. Crowleys Ridge.

**Panicum lanuginosum* Ell. West Slope of Crowleys Ridge.

Panicum laxiflorum Lam. West Slope of Crowleys Ridge.

Panicum nitidum Lam. West Slope of Crowleys Ridge.

Panicum perlongum Nash. West Slope of Crowleys Ridge.

**Panicum scoparium* Lam. L'Anguille River Runoff System.

Paspalum floridanum Michx. Crowleys Ridge.

Paspalum laeve Michx. L'Anguille River Runoff System.

Paspalum pubiflorum Rupr. East Slope of Crowleys Ridge.

Phalaris canariensis L. L'Anguille River Runoff System.

Poa alsodes Gray. St. Francis Riveroff Foodplain. East Slope of Crowleys Ridge. West Slope of Crowleys Ridge.

Sorgum halepense (L.) Pers. St. Francis River Floodplain.

Sporobolus asper (Michx.) Kunth. West Slope of Crowleys Ridge.

Tridens flavus (L.) Hitchc. West Slope of Crowleys Ridge.

Tridens strictus (Nutt.) Nash. West Slope of Crowleys Ridge.

Cyperaceae

Carex sp. Crowleys Ridge.

Carex sp. Bayou DeView Runoff System.

**Cyperus erythrorhizos* Muhl. L'Anguille River Runoff System.

*Arkansas State University Herbarium Specimen

Cyperus flavescens L. L'Anguille River Runoff System.

Cyperus iria L. East Slope of Crowleys Ridge.

Cyperus ovularis (Michx.) Torr. Crowleys Ridge.

Cyperus pseudovegetus Steud. West Slope of Crowleys Ridge. Crowleys Ridge.

Cyperus strigosus L. Crowleys Ridge.

Eleocharis obtusa (Willd.) Schult. Crowleys Ridge.

Scirpus cyperinus (L.) Kunth. L'Anguille River Runoff System.

Commelinaceae

Tradescantia subaspera Ker. West Slope of Crowleys Ridge.

Tradescantia virginiana L. Bayou DeView Runoff System.

Juncaceae

Juncus effusus L. Bayou DeView Runoff System.

Juncus secundus Beauv. East Slope of Crowleys Ridge.

Luzula campestris (L.) DC. Crowleys Ridge.

Lilaceae

Allium bivalve (L.) Kuntz. L'Anguille River Runoff System.

Allium vineale L. St. Francis River Floodplain.

Smilax bona-nox L. East Slope of Crowleys Ridge. West Slope of Crowleys Ridge. St. Francis River Floodplain.

Smilax glauca Walt. West Slope of Crowleys Ridge. L'Anguille River Runoff System.

Smilax hispida Muhl. St. Francis River Floodplain.

Smilax rotundifolia L. East Slope of Crowleys Ridge. West Slope of Crowleys Ridge. Crowleys Ridge. St. Francis River Floodplain.

Trillium recurvatum Beck. West Slope of Crowleys Ridge.

Dioscoreaceae

Dioscorea villosa L. L'Anguille River Runoff System.

Amaryllidaceae

Agave virginica L. Crowleys Ridge.

Hypoxis hirsuta (L.) Coville. L'Anguille River Runoff System.

Hymenocallis coronaria (LeConte) Kunth. L'Anguille River Runoff System.

Narcissus incomparabilis Mill. St. Francis River Floodplain.

Iridaceae

Sisyrinchium arenicola Bickn. East Slope of Crowleys Ridge.

Orchidaceae

Spiranthes cernua (L.) Rich. West Slope of Crowleys Ridge.

ANGIOSPERMAE

DICOTYLEDONEAE

Salicaceae

Populus alba L. West Slope of Crowleys Ridge.

Populus deltoides Marsh. St. Francis River Floodplain. L'Anguille River Runoff System. Crowleys Ridge.

Salix interior Rowlee. St. Francis River Floodplain.

Salix nigra Marsh. West Slope of Crowleys Ridge.

Juglandaceae

Carya aquatica (Michx. f.) Nutt. L'Anguille River Runoff System.

Carya cordiformis (Wang.) K. Koch. East Slope of Crowleys Ridge.

Carya glabra (Mill.) Sweet. Crowleys Ridge.

Carya illinoensis (Wang.) K. Koch. Crowleys Ridge.

Carya laciniosa (Michx. f.) Loud. West Slope of Crowleys Ridge. Crowleys Ridge.

Carya ovalis (Wang.) Sarg. Crowleys Ridge.

Carya tomentosa (Poir.) Nutt. East Slope of Crowleys Ridge.

Betulaceae

Ostrya virginiana (Mill.) K. Koch. Crowleys Ridge.

Carpinus caroliniana Walt. West Slope of Crowleys Ridge. Crowleys Ridge.

Fagus grandifolia Ehrh. var. *caroliniana* (Loud.) Fern & Rehd. East Slope of Crowleys Ridge.

Quercus alba L. East Slope of Crowleys Ridge. Crowleys Ridge.

Quercus alba L. var. *latiloba* Sarg. East Slope of Crowleys Ridge.

Quercus lyrata Walt. L'Anguille River Runoff System.

Michael I. Johnson

Quercus macrocarpa Michx. East Slope of Crowleys Ridge.

Quercus marilandica Muenchh. Crowleys Ridge. West Slope of Crowleys Ridge.

Quercus muehlenbergii Engelm. West Slope of Crowleys Ridge. Crowleys Ridge.

Quercus nigra L. West Slope of Crowleys Ridge.

Quercus palustris Muenchh. Crowleys Ridge.

Quercus phellos L. Crowleys Ridge.

Quercus stellata Wang. Crowleys Ridge.

Quercus velutina Lam. East Slope of Crowleys Ridge.

Ulmaceae

Celtis laevigata Willd. East Slope of Crowleys Ridge.

Planera aquatica Gmel. L'Anguille River Runoff System.

Ulmus alata Michx. Crowleys Ridge. East Slope of Crowleys Ridge.

Ulmus americana L. East Slope of Crowleys Ridge.

Ulmus rubra Muhl. West Slope of Crowleys Ridge.

Moraceae

Maclura pomifera (Raf.) Schneid. East Slope of Crowleys Ridge.

Morus rubra L. West Slope of Crowleys Ridge. Crowleys Ridge.

Urticaceae

Loportea canadensis (L.) Gaud. West Slope of Crowleys Ridge.

Pilea pumila (L.) Gray. West Slope of Crowleys Ridge.

Loranthaceae

Phoradendron serotinum (Raf.) M. C. Johnst. L'Anguille River Runoff System.

Polygonaceae

Brunnichia cirrhosa Banks ex Gaertn. St. Francis River Floodplain.

Polygonum hydropiperoides Michx. West Slope of Crowleys Ridge. Crowleys Ridge.

Polygonum lapathifolium L. St. Francis River Floodplain. East Slope of Crowleys Ridge.

Polygonum pennsylvanicum L. Crowleys Ridge. East Slope of Crowleys Ridge.

Polygonum scandens L. St. Francis River Floodplain. West Slope of Crowleys Ridge.

Rumex acetosella L. St. Francis River Floodplain.

Rumex altissimus Wood. Crowleys Ridge.

Tovara virginiana (L.) Raf. West Slope of Crowleys Ridge.

Chenopodiaceae

Chenopodium album L. West Slope of Crowleys Ridge.

Chenopodium ambrosioides L. West Slope of Crowleys Ridge.

Chenopodium leptophyllum Nutt. Crowleys Ridge.

Amaranthaceae

Amaranthus hybridus L. West Slope of Crowleys Ridge.

Nyctaginaceae

Mirabilis nyctaginea (Michx.) MacM. West Slope of Crowleys Ridge.

Phytolaccaceae

Phytolacca americana L. West Slope of Crowleys Ridge. Crowleys Ridge.

Portulacaceae

Claytonia virginica L. East Slope of Crowleys Ridge. Bayou DeView Runoff System.

Caryophyllaceae

Cerastium semidecandrum L. East Slope of Crowleys Ridge.

Stellaria media (L.) Cyrill. St. Francis River Floodplain.

Ranunculaceae

Ranunculus abortivus L. St. Francis River Floodplain.

Ranunculus septentrionalis Poir. Bayou DeView Runoff System.

Berberidaceae

Podophyllum peltatum L. Crowleys Ridge.

Menispermaceae

Cocculus carolinus (L.) DC. West Slope of Crowleys Ridge.

Magnoliaceae

Liriodendron tulipifera L. Crowleys Ridge. West Slope of Crowleys Ridge.

Annonaceae

Asimina triloba (L.) Dunal. West Slope of Crowleys Ridge.

Lauraceae

Sassafras albidum (Nutt.) Nees. East Slope of Crowleys Ridge.

Sassafras albidum (Nutt.) Nees. var. *molle* (Raf.) Fern. Crowleys Ridge.

Brassicaceae

Brassica kaber (DC.) L.C. Wheeler. L'Anguille River Runoff System.

Brassica napus L. L'Anguille River Runoff System.

Capsella bursa-pastoris (L.) Medic. St. Francis River Floodplain.

Cardamine parviflora L. Crowleys Ridge.

Dentaria laciniata Muhl. ex Willd. West Slope of Crowleys Ridge.

Draba glabella Pursh. St. Francis River Floodplain.

Lepidium virginicum L. St. Francis River Floodplain. Crowleys Ridge.

Sibara virginica (L.) Rollins. Crowleys Ridge.

Hamamelidaceae

Liquidambar styraciflua L. Crowleys Ridge. East Slope of Crowleys Ridge.

Platanaceae

Platanus occidentalis L. Crowleys Ridge.

Rosaceae

Crataegus calpodendron (Ehrh.) Medic. L'Anguille River Runoff System.

Crataegus marshalli Eggl. West Slope of Crowleys Ridge.

Potentilla simplex Michx. Bayou DeView Runoff System.

Prunus angustifolia Marsh. West Slope of Crowleys Ridge.

Prunus hortulana Bailey. West Slope of Crowleys Ridge.

Prunus persca (L.) Batsch. St. Francis River Floodplain.

Prunus serotina Ehrh. Crowleys Ridge.

Rosa carolina L. S. Francis River Floodplain. East

Slope of Crowleys Ridge.

Rosa gallica L. East Slope of Crowleys Ridge

Rosa multiflora Thunb. St. Francis River Floodplain.

Rosa setigera Michx. West Slope of Crowleys Ridge.

Rubus bifrons Vest. St. Francis River Floodplain.

Rubus flagellaris Willd. Bayou DeView Runoff System.

Rubus ostryifolius Rydb. Crowleys Ridge.

Rubus strigosus Michx. St. Francis River Floodplain. Crowleys Ridge.

Spiraea prunifolia Sieb. & Zucc. var. *plena* Schneid. West Slope of Crowleys Ridge.

Fabaceae

Amorpha fruticosa L. St. Francis River Floodplain.

Apios americana Medic. West Slope of Crowleys Ridge.

Baptisia leucantha T. & G. East Slope of Crowleys Ridge.

Baptisia leucophaea Nutt. L'Anguille River Runoff System.

Cassia fasciculata Michx. Crowleys Ridge. East Slope of Crowleys Ridge.

Cercis canadensis L. St. Francis River Floodplain.

Clitoria mariana L. Crowleys Ridge. East Slope of Crowleys Ridge.

Desmanthus illinoensis (Michx.) MacM. St. Francis River Floodplain. Crowleys Ridge.

Desmodium lineatum DC. Crowleys Ridge.

Desmodium marilandicum (L.) DC. Crowleys Ridge.

Gleditsia triacanthos L. East Slope of Crowleys Ridge.

Crowleys Ridge. Bayou DeView Runoff System. St. Francis River Floodplain.

Lathyrus hirsutus L. St. Francis River Floodplain.

Lespedeza cuneata (Dumont) G. Don. West Slope of Crowleys Ridge. Crowleys Ridge.

Lespedeza repens (L.) Bart. West Slope of Crowleys Ridge.

Lespedeza stuevei Nutt. West Slope of Crowleys Ridge.

Melilotus officinalis (L.) Lam. St. Francis River Floodplain.

Pueraria lobata (Willd.) Ohwi. Crowleys Ridge.

Robinia pseudo-acacia L. West Slope of Crowleys Ridge. L'Anguille River Runoff System.

Michael I. Johnson

Sesbania exaltata (Raf.) A. W. Hill. St. Francis River Floodplain.

Stylosanthes biflora (L.) BSP. Crowleys Ridge.

Tephrosia virginiana (L.) Pers. Crowleys Ridge. East Slope of Crowleys Ridge.

**Trifolium arvense* L. Bayou DeView Runoff System.

Trifolium incarnatum L. L'Anguille River Runoff System.

Trifolium pratense L. St. Francis River Floodplain.

Trifolium procumbens L. St. Francis River Floodplain.

Vicia angustifolia Reichard. Bayou DeView Runoff System. St. Francis River Floodplain.

Vicia villosa Roth. St. Francis River Floodplain.

Oxalidaceae

Oxalis corniculata L. West Slope of Crowleys Ridge.

Oxalis stricta L. Crowleys Ridge. Bayou DeView Runoff System.

Oxalis violaceae L. West Slope of Crowleys Ridge. L'Anguille River Runoff System.

Geraniaceae

Geranium carolinianum L. Crowleys Ridge. Bayou DeView Runoff System.

Geranium carolinianum L. var. *confertiflorum* Fern. St. Francis River Floodplain.

Euphorbiaceae

Acalypha rhomboidea Raf. East Slope of Crowleys Ridge.

Acalypha virginica L. West Slope of Crowleys Ridge.

Croton capitatus Michx. East Slope of Crowleys Ridge.

Crotonopsis linearis Michx. West Slope of Crowleys Ridge.

Euphorbia maculata L. West Slope of Crowleys Ridge.

Anacardiaceae

Rhus copallina L. West Slope of Crowleys Ridge.

Rhus glabra L. Crowleys Ridge.

Rhus radicans L. East Slope of Crowleys Ridge. Crowleys Ridge. Bayou DeView Runoff System.

Aquifoliaceae

Ilex coriacea (Pursh) Chapm. East Slope of Crowleys Ridge.

Ilex decidua Walt. West Slope of Crowleys Ridge. Crowleys Ridge.

Ilex verticillata (L.) Gray var. *padifolia* (Willd.) T. & G. Crowleys Ridge. Bayou DeView Runoff System.

Staphyleaceae

Staphylea trifolia L. West Slope of Crowleys Ridge.

Aceraceae

Acer negundo L. West Slope of Crowleys Ridge. St. Francis River Floodplain.

Acer rubrum L. Crowleys Ridge.

Acer saccharinum L. St. Francis River Floodplain. West Slope of Crowleys Ridge. Crowleys Ridge.

Hippocastanaceae

Aesculus pavia L. East Slope of Crowleys Ridge. Bayou DeView Runoff System. Crowleys Ridge.

Rhamnaceae

Rhamnus caroliniana Walt. West Slope of Crowleys Ridge.

Vitaceae

Ampelopsis arborea (L.) Koehne. Crowleys Ridge.

Parthenocissus quinquefolia (L.) Planch. West Slope of Crowleys Ridge. Crowleys Ridge.

Vitis cinerea Engelm. ex Millardet. Bayou DeView Runoff System.

Vitis rotundifolia Michx. East Slope of Crowleys Ridge. West Slope of Crowleys Ridge. Crowleys Ridge.

Malvaceae

Gossypium hirsutum L. Crowleys Ridge.

Hibiscus lasiocarpus Cav. West Slope of Crowleys Ridge.

Hibiscus militaris Cav. L'Anguille River Runoff System.

Hibiscus moscheutos L. East Slope of Crowleys Ridge.

Sida spinosa L. L'Anguille River Runoff System. West Slope of Crowleys Ridge.

Hypericaceae

Hypericum densiflorum Pursh. Bayou DeView Runoff System.

Hypericum drummondii (Grev. & Hook.) T. & G. West

*Arkansas State University Herbarium Specimen

Slope of Crowleys Ridge.

Hypericum hypericoides (L.) Crantz. Crowleys Ridge.

Hypericum stragalum Adams & Robson. Crowleys Ridge.

Violaceae

Viola eriocarpa Schwein. var. *leiocarpa* Fern. & Weig. West Slope of Crowleys Ridge.

Viola missouriensis Greene. Crowleys Ridge.

Viola pedata L. West Slope of Crowleys Ridge.

Viola rafinesquii Greene. St. Francis River Floodplain. Crowleys Ridge.

Viola triloba. (Schwein) Ging. West Slope of Crowleys Ridge.

Passifloraceae

Pasiflora incarnata L. West Slope of Crowleys Ridge.

Pasiflora lutea L. West Slope of Crowleys Ridge.

Lythraceae

Ammannia coccinea Rottb. Crowleys Ridge.

Rotala ramosior (L.) Koehne. Crowleys Ridge.

Onagraceae

Ludwigia adscendens (L.) H. Hara. Crowleys Ridge.

Ludwigia alternifolia L. St. Francis River Floodplain. Crowleys Ridge.

Oenothera biennis L. Crowleys Ridge.

Oenothera laciniata Hill. Bayou DeView Runoff System.

Oenothera pilosella Raf. East Slope of Crowleys Ridge.

Oenothera speciosa Nutt. St. Francis River Floodplain.

Araliaceae

Aralia spinosa L. West Slope of Crowleys Ridge.

Apiaceae

Chaerophyllum tainturieri Hook. St. Francis River Floodplain.

Cicuta maculata L. St. Francis River Floodplain.

Eryngium yuccifolium Michx. St. Francis River Floodplain.

Ptilimnium nuttallii (DC.) Britt. East Slope of Crowleys Ridge.

Torilis arvensis (Huds.) Link. East Slope of Crowleys Ridge.

Nyssaceae

Nyssa aquatica L. Crowleys Ridge.

Cornaceae

Cornus florida L. West Slope of Crowleys Ridge.

Ericaceae

Vaccinium arboreum Marsh. Crowleys Ridge.

Primulaceae

**Lysimachia lanceolata* Walt. L'Anguille River Runoff System.

Ebenaceae

Diospyros virginiana L. East Slope of Crowleys Ridge.

Oleaceae

Forestiera acuminata (Michx.) Poir. L'Anguille River Runoff System.

Fraxinus americana L. Crowleys Ridge.

Ligustrum amurense Carr. St. Francis River Floodplain.

Ligustrum sinense Lour. West Slope of Crowleys Ridge.

Ligustrum vulgare L. St. Francis River Floodplain.

Apocynaceae

Amsonia tabernaemontana Walt. Bayou DeView Runoff System.

Trachelospermum difforme (Walt.) Gray. West Slope of Crowleys Ridge. Crowleys Ridge.

Asclepiadaceae

Asclepias variegata L. St. Francis River Floodplain.

Asclepias viridis Walt. East Slope of Crowleys Ridge.

Cynanchum laeve (Michx.) Pers. East Slope of Crowleys Ridge.

Matelea gonocarpa (Walt.) Shinn. West Slope of Crowleys Ridge.

Convolvulaceae

Calystegia sepium (L.) R. Br. West Slope of Crowleys Ridge.

Ipomoea hederacea (L.) Jacq. West Slope of Crowleys Ridge. Crowleys Ridge.

Ipomoea pandurata (L.) G.F.W. Meyer Crowleys Ridge.

Polemoniaceae

Phlox pilosa L. Bayou DeView Runoff System.

Hydrophyllaceae

Hydrolea ovata Nutt. East Slope of Crowleys Ridge.

Phacelia dubia (L.) Trel. L'Anguille River Runoff System.

Phacelia ranunculacea (Nutt.) Const. Crowleys Ridge.

Verbenaceae

Lippia lanceolata Michx. Crowleys Ridge.

Laminaceae

Lamium amplexicaule L. St. Francis River Floodplain.

Lycopus rubellus Moench. East Slope of Crowleys Ridge.

Perilla frutescens (L.) Britt. West Slope of Crowleys Ridge.

Prunella vulgaris L. var. *lancoolata* (Bart.) Fern. West Slope of Crowleys Ridge.

Pycnanthemum flexuosum (Walt.) BSP. West Slope of Crowleys Ridge. East Slope of Crowleys Ridge.

Pycnanthemum incanum (L.) Michx. East Slope of Crowleys Ridge. Crowleys Ridge.

Scutellaria parvula Michx. L'Anguille River Runoff System.

Solanaceae

Physalis angulata L. East Slope of Crowleys Ridge. Crowleys Ridge.

Physalis heterophylla Nees. East Slope of Crowleys Ridge.

Physalis pubescens L. var. *grisea* Waterfall. Crowleys Ridge.

Solanum americanum Mill. Crowleys Ridge.

Solanum carolinense L. Crowleys Ridge.

Solanum tuberosum L. West Slope of Crowleys Ridge.

Scrophulariaceae

Agalinis tenuifolia Vahl. Crowleys Ridge.

Linaria canadensis (L.) Dumont. Bayou DeView Runoff System.

Penstemon tubaeiflorus Nutt. St. Francis River Floodplain.

Verbascum blattaria L. St. Francis River Floodplain.

Verbascum thapsus L. West Slope of Crowleys Ridge.

Bignoniaceae

Anisostichus capreolata (L.) Bureau. East Slope of

Crowleys Ridge. West Slope of Crowleys Ridge.

Campsis radicans (L.) Seem. West Slope of Crowleys Ridge. St. Francis River Floodplain. Crowleys Ridge.

Acanthaceae

Ruellia humilis Nutt. West Slope of Crowleys Ridge.

Ruellia pinetorum Fern. East Slope of Crowleys Ridge.

Plantaginaceae

Plantago aristata Michx. St. Francis River Floodplain.

Rubiaceae

Cephalanthus occidentalis L. East Slope of Crowleys Ridge.

Diodia virginia L. Crowleys Ridge.

Galium aparine L. St. Francis River Floodplain.

Houstonia minima Beck. Crowleys Ridge.

Houstonia tenuifolia Nutt. St. Francis River Floodplain.

Caprifoliaceae

Lonicera japonica Thunb. West Slope of Crowleys Ridge.

Sambucus canadensis L. West Slope of Crowleys Ridge.

Valerianaceae

Valerianella locusta (L.) Betcke. Bayou DeView Runoff System. L'Anguille River Runoff System.

Valerianella radiata (L.) Dufur. St. Francis River Floodplain.

Cucurbitaceae

Melothria pendula L. East Slope of Crowleys Ridge.

Sicyos angulatus L. St. Francis River Floodplain.

Campanulaceae

Campanula americana L. Bayou DeView Runoff System.

Specularia biflora (R. & P.) Fisch. & Mey. St. Francis River Floodplain.

Specularia perfoliata (L.) A. DC. St. Francis River Floodplain.

Lobelia cardinalis L. Crowleys Ridge.

Lobelia inflata L. Crowleys Ridge.

Asteraceae

Achillea millefolium L. East Slope of Crowleys Ridge.

Ambrosia artemisifolia L. East Slope of Crowleys Ridge.

Ambrosia bidentata Michx. East Slope of Crowleys Ridge.

Ambrosia trifida L. St. Francis River Floodplain.

Anthemis cotula L. St. Francis River Floodplain. Crowleys Ridge.

Aster lateriflorus (L.) Britt. Crowleys Ridge.

Aster vimineus Lam. Crowleys Ridge.

Aster sp. St. Francis River Floodplain. L'Anguille River Runoff System .

Aster sp. West Slope of Crowleys Ridge. Crowleys Ridge.

Aster sp. West Slope of Crowleys Ridge.

Bidens aristosa (Michx.) Britt. East Slope of Crowleys Ridge. Crowleys Ridge.

Bidens bipinnata L. West Slope of Crowleys Ridge.

Boltonia asteroides (L.) L'Her. St. Francis River Floodplain. West Slope of Crowleys Ridge. Crowleys Ridge.

Boltonia diffusa Ell. Crowleys Ridge.

Cardus altissimus L. East Slope of Crowleys Ridge.

Carduus spinosissimus Walt. L'Anguille River Runoff System.

Coreopsis tinctoria Nutt. St. Francis River Floodplain. East Slope of Crowleys Ridge.

Eclipta alba (L.) Hassk. St. Francis River Floodplain.

Elephantopus carolinianus Willd. East Slope of Crowleys Ridge. West Slope of Crowleys Ridge.

Erechtites hieracifolia (L.) Raf. East Slope of Crowleys Ridge. West Slope of Crowleys Ridge.

Erigeron annuus (L.) Pers. St. Francis River Floodplain.

Erigeron canadensis L. St. Francis River Floodplain. Crowleys Ridge.

Erigeron strigosus Muhl. ex Willd. East Slope of Crowleys Ridge.

Eupatorium coelestinum L. West Slope of Crowleys Ridge

Eupatorium incarnatum Walt. East Slope of Crowleys Ridge. West Slope of Crowleys Ridge.

Eupatorium rugosum Houtt. West Slope of Crowleys Ridge.

Eupatorium serotinum Michx. East Slope of Crow-

leys Ridge. Crowleys Ridge. West Slope of Crowleys Ridge.

Gnaphalium obtusifolium L. Crowleys Ridge.

Helenium amarum (Raf.) Rock. East Slope of Crowleys Ridge.

Helianthus angustifolius L. L'Anguille River Runoff System. West Slope of Crowleys Ridge.

Helianthus annuus L. Crowleys Ridge.

Helianthus divaricatus L. Crowleys Ridge.

Helianthus microcephalus T. & G. Crowleys Ridge.

Iva annua L. St. Francis River Floodplain.

Krigia dandelion (L.) Nutt. Bayou DeView Runoff System.

Krigia oppositifolia Raf. Bayou DeView Runoff System.

Lactuca floridana (L.) Gaertn. West Slope of Crowleys Ridge.

Liatris punctata Hook. East Slope of Crowleys Ridge.

Liatris squarrosa (L.) Michx. Crowleys Ridge.

Polymnia uvedalia L. West Slope of Crowleys Ridge.

Pyrrhophappus carolinianus (Walt.) DC. St. Francis River Floodplain. Crowleys Ridge.

Rudbeckia hirta L. East Slope of Crowleys Ridge.

Senecio glabellus Poir. St. Francis River Floodplain.

Solidago altissima L. West Slope of Crowleys Ridge.

Solidago erecta Pursh. Crowleys Ridge.

Solidago graminifolia (L.) Salisb. Crowleys Ridge.

Solidago missouriensis Nutt. L'Anguille River Runoff System.

Solidago odora Ait. Crowleys Ridge.

Solidago radula Nutt. West Slope of Crowleys Ridge.

Solidago rugosa Mill. St. Francis River Floodplain.

Taraxacum officinale Wiggers. St. Francis River Floodplain.

Verbesina alternifolia (L.) Britt. ex Kearney. East Slope of Crowleys Ridge.

Verbesina virginica L. East Slope of Crowleys Ridge. West Slope of Crowleys Ridge. Crowleys Ridge.

Vernonia baldwini Torr. St. Francis River Floodplain. West Slope of Crowleys Ridge.

Xanthium strumarium L. West Slope of Crowleys Ridge. St. Francis River Floodplain.

Michael I. Johnson

LITERATURE CITED

- Dale, E. E., Jr. 1963. Literature on vegetation of Arkansas. Proc. Ark. Acad. Sci. 17:50-60.
- Duncan, W. H. 1967. Woody vines of the southeastern states. Sida 3:1-76.
- Fernald, M. L. 1950. Gray's Manual of Botany. 8th ed. American, New York. Ixiv + 1632 pp.
- Gleason, H. A. 1952. The New Britton and Brown Illustrated Flora of the Northeastern United States and Adjacent Canada. The New York Botanical Garden, New York. 3 vol.
- Gleason, H. A. and A. Cronquist. 1968. Manual of Vascular Plants of the Northeastern United States and Adjacent Canada. D. Van Nostrand Co., Inc., Princeton, N. J. li + 810 pp.
- Radford, A. E., H. E. Ahles, C. R. Bell. 1964. Guide to the Vascular Flora of the Carolinas. Univ. North Carolina Book Exchange, Chapel Hill, N. C. 383 pp.
- Shanks, R. E. and A. J. Sharp. 1963. Summer Key to Tennessee Trees. The University of Tennessee Press, Knoxville. 24 pp.
- U. S. Department of Agriculture. Soil Conservation Service. 1963. General Soil Map of Poinsett County, Arkansas. Little Rock, Arkansas.
- U. S. Department of Commerce. Bureau of the Census. County and City Data Book. U. S. Government Printing Office. Washington, D. C. xi + 673 pp.
- U. S. Department of Commerce. Environmental Science Service Bureau. 1967-1968. Climatological Data of Arkansas. vol. 72-73.

The Effects of Urethan on Fish Epithelial And Fibroblast Cells in Vitro

Leland F. Morgans

Department of Biology

University of Arkansas at Little Rock

Little Rock, Arkansas 72204

ABSTRACT

The effects of urethan on RTG-2 and FHM cells were studied *in vitro*. by using the mitotic index, it was determined that 0.3 percent urethan caused an increase in the rate of cell division while higher concentrations (0.6, 0.9, 1.2, and 1.5 percent) caused either a decrease in the rate or a cessation of cell division. Concentrations of urethan higher than 1.5 percent killed the cells. The mitotic index data also indicated that epithelial cells continued to divide at a higher concentration of urethan than did the fibroblast cells.

The morphological effects of urethan on the two cell lines were also investigated. These effects included vacuolization of the cytoplasm, lobed and enlarged nuclei, and in some cells the cytoplasm almost completely disappeared and the nucleus developed a thick membrane around it so that the cells resembled small lymphocytes.

INTRODUCTION

Research on urethan is not new. Ever since it was first found to be carcinogenic (Nettleship and Henshaw, 1943), much work has been done with this compound. However, to the author's knowledge no research with urethan has been done at the cellular level. Tissues have

been examined histologically *in vivo* and different cell types have been studied using tissue explants *in vitro*. Therefore, this problem was undertaken to see if the effects of urethan *in vivo* can be duplicated *in vitro*. Also, the author wanted to ascertain if urethan had the same effect on fish cells as it did on mammalian cells.

This paper is concerned with the effects of urethan on mitotic rates and cell morphology. Urethan is also referred to as ethyl carbamate urethane, and ethyl urethan in the literature. The author will only use the terms ethyl carbamate and urethan.

Materials and Methods

In this project two cell lines were maintained. One was a fibroblast line established from gonads of fingerling rainbow trout, *Salmo gairdneri* the other an epithelial line taken from skin tissue posterior to the anus of the northern fathead minnow, *Pimephales promelas*. The fibroblast and epithelial cell lines are referred to as the RTG-2 and FHM cell lines, respectively. Both cell lines were obtained from Dr. Kenneth E. Wolf at the Eastern Fish Disease Laboratory in Kearneyville, West Virginia.

The cell lines were maintained as monolayers in milk dilution bottles. They were grown in a medium consisting of Eagle's minimum essential medium (84 percent), fetal bovine serum (1 percent) L-glutamine (1 percent), and an antibiotic mixture of penicillin-streptomycin (5 percent — 250 units/ml).

Because of the growth of the cell cultures, they had to be diluted and transferred every two or three weeks. All of the transfers and most of the other work involving the cultures were performed in a sterile hood which was disinfected with isopropyl alcohol immediately before use.

A 5 percent stock solution of urethan was prepared and sterilized by filtration through a Millipore filter. It was readily soluble in the growth medium.

In order to estimate which concentrations of urethan were lethal, the cells were grown on coverslips in Leighton tubes. At 0 hours, growth medium containing different concentrations of urethan was added. Controls were also run in which only growth medium was added. After 72 hours the coverslips were removed and the cells were fixed in 10 percent formalin, hydrated, stained with Harris' hematoxylin (15 minutes), dehydrated with alcohol, cleared with xylene, mounted on slides, and observed with a microscope. If cells adhered to the coverslips they were considered to be alive. If there were no cells on the coverslips, the cells were considered dead and that concentration of urethan was considered lethal (2.0 percent). This process was done with both cell lines (RTG-2 and FHM). After the toxic concentration of urethan was ascertained five different sublethal concentrations of urethan were prepared — 0.3 percent, 0.6 percent, 0.9 percent, 1.2 percent and 1.5 percent. These concentrations of urethan were made up in the growth medium. A control was also prepared containing only growth medium (no urethan). The cells were then grown on coverslips, treated with various concentrations of urethan (including the control) for 72 hours, and stained with hematoxylin as described in the previous paragraph. Ten slides per treatment for each cell line were prepared

in this manner making a total of 120 slides. With these slides, the rate of cell division was estimated by using the mitotic index (Paul, 1960). In this procedure 1000 cells were selected at random on a slide. Of these 1000 cells, the number of nondividing and dividing cells are recorded. By dividing the number of dividing cells by the total number of cells, the percentage of dividing cells is obtained. The rate of cell division is a mitotic index. Since 10 slides were used for each treatment, a total of 10,000 cells were counted for each treatment.

In order to estimate which concentrations of urethan were significantly different from each other and from the control, Duncan's multiple range test was performed on both cell lines (Steel and Torrie, 1960).

The effects of urethan on cell morphology were observed by staining the cells with Harris' hematoxylin. The same hematoxylin stained cells used in the mitotic index experiment were used for studying morphology.

Results and Discussion

Urethan does have an effect on the mitotic rate or RTG-2 cells (table I, table II). Table I illustrates the following points: 0.3 percent urethan caused an increase in the rate of cell division; 0.6 percent urethan caused the cell division rate to decrease; 0.9 percent, 1.2 percent, and 1.5 percent urethan caused cell division to cease; and 2.0 percent urethan was lethal to the cells.

TABLE I
 MITOTIC INDEX DATA FOR THE
 RTG-2 CELL LINE

Concentration of Urethan	Per Cent in Mitosis	Number of Dividing Cells/ 1000 Cells
0.0% (control)	1.83	18.3
0.3%	2.69	26.9
0.6%	1.51	15.1
0.9%	0.00	0.0
1.2%	0.00	0.0
1.5%	0.00	0.0
2.0%	lethal	lethal

TABLE II
 DUNCAN'S MULTIPLE RANGE TEST OF MITOTIC INDEX
 DATA FOR THE RTG-2 CELL LINE

Concentration of Urethan	0.9%	1.2%	1.5%	0.6%	0.0%	0.3%
Number of Dividing Cells/ 1000 Cells	0.0	0.0	0.0	15.1	18.3	26.9

Leland F. Morgans

Duncan's Multiple Range test was used in order to estimate which treatments were significantly different from each other at the .05 level (table II). In this table any two means not underscored by the same line are significantly different from each other. In order for lines to be drawn in this manner the means must be ranked. For example, by using this test it was noted that the control and 0.3 percent urethan differed significantly in cell division rate.

Urethan also had an effect on the mitotic rate of FHM cells (table III, table IV). Table III shows that on FHM cells urethan caused an increase in the rate of cell division at low concentrations (0.3 percent); at higher concentrations of urethan (0.9 percent) the rate of cell division decreased; at still higher concentrations of urethan (1.2 percent and 1.5 percent) cell division ceased; and finally, 2 percent urethan was toxic to the cells.

TABLE III
MITOTIC INDEX DATA FOR THE FRM CELL LINE

Concentration of Urethan	Per Cent in Mitosis	Number of Dividing Cells/1000 Cells
0.0% (control)	2.38	23.8
0.3%	3.78	37.8
0.6%	2.78	27.8
0.9%	1.39	13.9
1.2%	0.00	0.0
1.5%	0.00	0.0
2.0%	lethal	lethal

TABLE IV
DUNCAN'S MULTIPLE RANGE TEST OF MITOTIC INDEX DATA FOR THE FHM CELL LINE

Concentration of Urethan	1.2%	1.5%	0.9%	0.0%	0.6%	0.3%
Number of Dividing Cells/1000 Cells	0.0	0.0	13.9	23.8	27.8	37.8

The Duncan's Multiple Range test was also performed on the FHM cell line (table IV). As in table II, the test indicated which treatments were significantly different from each other at the .05 level. For example, the cell division rate in 0.3 percent urethan was significantly higher than either the control or 0.6 percent urethan.

Thus, the evidence from this research indicates that various sublethal concentrations of urethan can cause the rate of cell division to rise, fall, or cease. Concentrations

of urethan higher than 1.5 percent killed the cells in both the RTG-2 and FHM cell lines. Battle and Hisaoka (1952) also observed these phenomena when they observed that urethan caused epithelial hyperplasia in the teleost embryo, *Brachydanio rerio*. Hyperplasia was most evident on the ventral surface of the pericardial sac, the ventrolateral trunk regions, and occasionally on the tail. Bucher (1949) reported that urethan caused the mitotic coefficient at first to rise and then drop in tissue cultures. He concluded that the actions of urethan depended on the dose, length of action, and biological cellular resistance.

This study has also shown that epithelial cells were more resistant to urethan than fibroblast cells (table I and table III). Epithelial cells continued to divide in 0.9 percent urethan, whereas fibroblast cells ceased to divide. Globerson and Aurebach (1965) observed a similar phenomenon when they found that the epithelial cells of thymus and lung explants survived 1 percent urethan for four days; whereas the lymphocytes, alveolar tissue, and connective tissue underwent extensive necrosis.

There appeared to be two typical shapes in the RTG-2 cells. One was a triangular shaped cell with long protoplasmic extensions; the other was spindle-shaped. The FHM cells also assumed two basic shapes, viz., a rectangular or polygonal shape cell and a triangular shaped cell.

The concentrations of urethan did not change the basic shapes of the cells with one notable exception. Concentrations of 1.2 percent and 1.5 percent urethan caused many of the cells to lose most of their cytoplasm; a thick membrane appeared around the nucleus and the nucleus became darker. In many respects this aberrant type of cell looked like a small lymphocyte.

Another major effect of urethan on the cells was the appearance of vacuoles in the cytoplasm. This vacuolated appearance of the cells began at 0.6 percent urethan and became more pronounced as the concentrations of urethan increased. Urethan also caused some of the nuclei to become lobed and enlarged.

There appeared to be no difference in the effect of urethan on cellular morphology in the two cell lines.

Geirebach (1939) observed many of these cellular aberrations when he worked with the effects of urethan on chick fibroblast cells. He reported that urethan caused the cells to become vacuolated and pyknotic. Also, there was a "rounding" of the cells. Haddow and Sexton (1964) found that urethan caused epithelial tumor cells to revert to a fibrous structure, with spindle cells and abundant stroma. The present study did not demonstrate any changes in the basic structure of the epithelial or fibroblast cells, but it should be noted that it was concerned with "normal" cells whereas Haddow and Sexton worked with tumor cells.

Summary

The effects of urethan on RTG-2 and FHM cells were studied *in vitro*. By using the mitotic index, it was found that 0.3 percent urethan caused an increase in the rate of cell division while higher concentrations (0.6, 0.9, 1.2 and 1.5 percent) caused either a decrease in the rate of cell division or a cessation of cell division. Concentrations of urethan higher than 1.5 percent killed the cells. The mitotic index data also indicated that epithelial cells continued to divide at a higher concentration of urethan than did the fibroblast cells.

The morphological effects of urethan on the two cell lines were also investigated. These effects included vacuolization of the cytoplasm, lobed and enlarged nuclei, and in some cells the cytoplasm almost completely disappeared and the nucleus developed a thick membrane around it so that the cells resembled small lymphocytes.

LITERATURE CITED

- Battle, Helen I., and K. K. Hisaoka. 1952. Effects of thyl carbamate (urethan) on early development of the teleost *Brachydanio rerio*. *Cancer Res.* 12(1): 334-339.
- Bucher, O. 1949. The action of ethyl urethan on the course and speed of division in tissue cultures. *Schweig. Med. Wachenschr* 79(21): 483 (Biol. Abstracts).
- Goiersbach, U. 1939. Uber den einflussder narkose (urethan) auf gewebekultran. *Archiv. Exp. Zellforsch bes Gewebezucht* 23(2): 210-219.
- Globerson, Amelia, and R. Aurebach. 1965. *In vitro* studies on thymus and lung differentiation following urethan treatment. *Wister. Inst. Symp. Monogr.* 4(1): 3-19.
- Haddow, A., and W. A. Sexton. 1946. Influence of carbamic esters on experimental animal tumors. *Nature* 157 (3990): 500-503.
- Neilson, W. A., T. A. Knott, and P. W. Carhart. 1960. Webster's new international dictionary of the english language. 2nd ed. G. and C. Merriam Co., Springfield, Mass. 3194 p.
- Nettleship, A., and P. S. Henshaw. 1943. Induction of pulmonary tumors in mice with ethyl carbamate. *U. S. Nat. Cancer Inst.* 4(2): 309-319.
- Paul, J. 1960. Cell and tissue culture. 2nd. ed. Williams and Wilkens. Baltimore. 312 p.
- Steel, R. G. D., and J. H. Torrie. 1960. Principles and procedures of statistics. McGraw-Hill Book Co., New York. 481 p.

The Relative Abundance, Seasonal Distribution and Taxonomy of the Sphingidae of Northeast Arkansas

Charles L. Selman¹ and Harvey E. Barton²

¹Dept. of Entomology, Ohio State University,
Columbus, Ohio 43210

²Division of Biological Sciences
Arkansas State University
State University, Arkansas 72467

ABSTRACT

A total of 38 species of sphingids, with keys and descriptions, are reported from Northeast Arkansas. Graphs and tables are presented to show relative abundance and seasonal distribution. Drawings of genitalia, fore tibiae, and forewings, as well as photographs of species in the key are included.

INTRODUCTION

This report is based on records of 671 specimens of adult Sphingidae which were collected from northeast Arkansas in 1970. In addition, we have included a few records from other sources. A key and descriptions for 38 species of sphingids common to northeast Arkansas are included. The location implied, if not otherwise specifically stated, is Craighead County, Arkansas. A few records from other counties are used, especially when no specimens of these species were trapped in Craighead County.

Two traps were utilized in this study, each equipped with omni-directional, 15 watt blacklight lamps. The traps were modified versions of the one recommended by the Entomological Society of America (Coop. Econ. Ins. Rpt., 1966) in that we used a one-gallon jar containing 70 percent isopropyl alcohol for collection of the moths. The traps were emptied daily. All of the sphingids from Craighead County were identified and recorded; however, to save time, only the rarely occurring moths were recorded from Fulton County. We were generally aware of the sphingids that were less abundant due to our previous collecting experiences.

The Fulton County trap was located three miles southwest of Mammoth Spring, Arkansas. The area is primarily oak-hickory forest. The second trap was located approximately eighty miles south-east of Mammoth Spring and four miles north-east of Jonesboro in Craighead County, Arkansas. Craighead County is in the Mississippi alluvial plain, and most of the land is in tillage.

This study was first initiated to determine information on these moths, not to develop a taxonomic key. However, it became obvious that there were no adequate keys for this area. Burton and Drew (1967) made a key for

a number of Oklahoma sphingids, but failed to give adequate diagnostic characters to separate several superficially similar moths, namely *Ceratomia hageni*, *Ceratomia undulosa*, and *Ceratomia catalpae*. Further, their key contains only 26 species, while more sphingids are known to occur in Arkansas.

The key in this paper is designed to help the student separate species with certainty; however, some very helpful works for the lepidopterist are available (Forbes, 1948; Hodges, 1971; Holland, 1968; Kimball, 1965; and Mitchel and Zim, 1964), if additional sources are needed. Also, while Hodges (1971) includes virtually all of the sphingids of America North of Mexico, local keys will none-the-less be indispensable. This has been adequately demonstrated in Arkansas by Rouse (1965, 1968, 1969, and 1970.) While Klots (1951) illustrates nearly all butterflies east of the Great Plains, Rouse's keys of four families of butterflies found in Arkansas greatly speeds up the identification process by eliminating those species that do not occur in the state. Also, McDunnough (1938) lists 106 species, and a number of forms of Sphingidae that occur in the United States and Canada, while Hodges (1971) lists 115 species, but our local key reduces this number by nearly two-thirds.

Beebe (1952), in his sampling of Michigan Lepidoptera, states that light-trapping is a useful tool in determining the relative abundance of some species. Rihard (1955) made a light-trap study of 40 species of moths that occur in Texas to determine their seasonal occurrence throughout the year. Consequently, light-trapping, with its limitations, has proven of value in furnishing much information on moths.

A knowledge of periods of activity is badly needed for many moths that occur in Arkansas, and it is the hope of the authors that this paper will help reduce the gap. Only a few Sphingids, namely *Manduca sexta* and

The Relative Abundance, Seasonal Distribution and Taxonomy of Sphingidae of Northeast Arkansas

Manduca quinquemaculata, have received any notable attention (Bucher, 1967; Gentry, et al, 1967; McFadden, et al, 1968; McFadden, 1969; Sparks, 1968; and Stewart, et al, 1967 and 1968). This is to be expected, however, since these moths are economically important. Freeman (1938) recorded 32 species of Sphingidae from Arkansas. Also Taylor and Taylor (1965) reported 24 species from the Mississippi Gulf Coast.

Of the 38 species in our key, Tietz (1952) lists food plants and references on the life history for 34 of these species. Further, Tietz records 48 species of Sphingidae from Pennsylvania.

SEASONAL ABUNDANCE

Many of the records in Table I were taken at irregular intervals and it was not possible to indicate the period of greatest abundance for each species. Thus, Figure 1 and 2 show the seasonal abundance of those species for which 10 or more specimens were collected in our traps in 1970. (with the exception of *Hemaris diffinis*). In addition to the data shown in Figure 2, one specimen of *Xylophanes tersa* was taken on October 27.

TABLE I. Sphingidae. Relative abundance and seasonal distribution of species in Northeast Arkansas.

SPECIES	TOTAL COLLECTED	EARLIEST DATE TAKEN	LATEST DATE TAKEN
<i>Ceratomia catalpae</i>	126	May 6	Sept. 10
<i>Paonias myops</i>	59	April 24	Sept. 1
<i>Darapsa myron</i>	59	May 5	Sept. 2
<i>Smerinthus jamaicensis</i>	58	May 5	Sept. 4
<i>Hyles lineata</i>	50	May 7	Oct. 5
<i>Ceratomia undulosa</i>	49	May 15	Sept. 3
<i>Paratreia plebeja</i>	38	May 6	Aug. 31
<i>Xylophanes tersa</i>	37	May 10	Oct. 27
<i>Cressonia juglandis</i>	29	May 4	Aug. 29
<i>Agrius cingulatus</i>	28	Sept. 8	Oct. 30
<i>Manduca quinquemaculata</i>	23	June 1	Oct. 1
<i>Hemaris diffinis</i>	21	May 15	
<i>Ceratomia hageni</i>	19	April 16	Sept. 3
<i>Deidamia inscripta</i>	16	April 9	May 8
<i>Manduca sexta</i>	16	May 27	Sept. 12
<i>Darapas pholus</i>	10	April 22	May 14
<i>Paonia excaecatus</i>	10	May 28	Aug. 20
<i>Sphecodina abbottii</i>	6	April 22	April 30
<i>Eumorpha pandorus</i>	4	July 8	Oct. 1
<i>Eumorpha achemon</i>	4	July 1	Aug. 12
<i>Manduca jasminearum</i>	2	June 11	June 22
<i>Ceratomia amyntor</i>	1	May 28	
<i>Dolba hylaeus</i>	1	Sept. 10	
<i>Erinnyis obscura</i>	1	Oct. 1	
<i>Pachysphinx modesta</i>	1	Oct. 7	
<i>Eumorpha fasciatus</i>	1	Sept. 9	
<i>Sphinx chersis</i>	1	Aug. 10	
<i>Sphinx drupiferarum</i>	1	May 8	

Figures 1 and 2 — Periods of activity of species for which 10 or more specimens were collected in our traps in 1970.

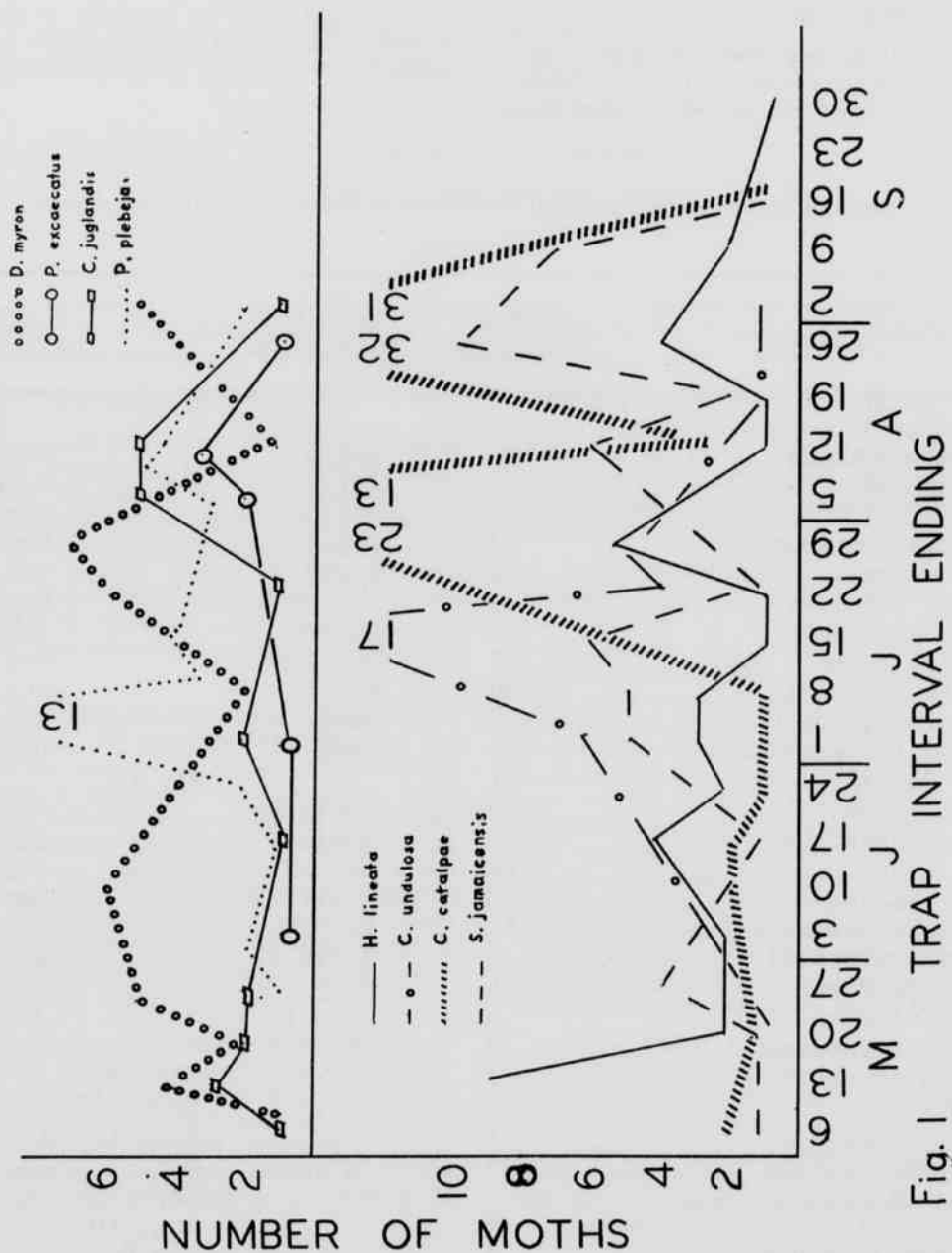


Fig. 1

The Relative Abundance, Seasonal Distribution and Taxonomy of Sphingidae of Northeast Arkansas

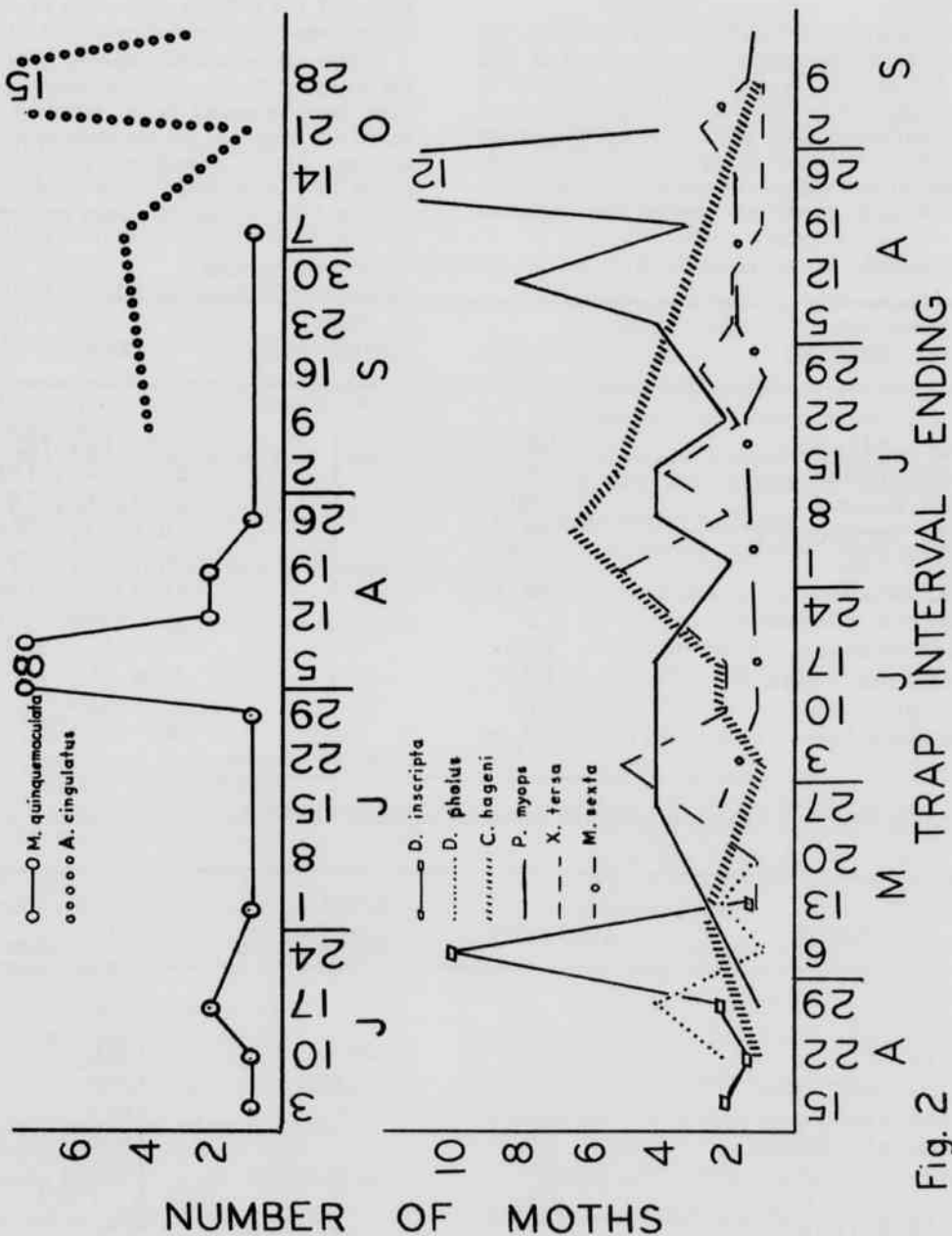


Fig. 2

**RELATIVE ABUNDANCE
AND SEASONAL DISTRIBUTION**

Table I includes all of the species of sphingids now known by the authors to occur in northeast Arkansas. The number of specimens of each species collected, and the earliest and latest dates of collection for each are indicated.

The earliest and latest records in the state for the active occurrence of sphingid adults are April 9 and October 30. No species is known by the authors to occur here throughout this entire period, but each is present during a particular part of it. Six species made their appearance in Arkansas in April, and thirteen, or almost one-half of the species recorded in the state, first appeared in May. Next, two species first appeared

in June, two in July, one in August, three in September, and two in October.

Table II includes those species that have been recorded in Arkansas but not specifically collected by the authors. This list is not meant to be complete with all records of these species, but rather a verification that the sphingids listed have been taken in Arkansas. Sphingids that the authors were able to inspect are included in the key.

Table III lists those species that the authors could not verify as having been recorded in Arkansas but that have been recorded in an adjacent state. Again, this list is not meant to be complete with all records of these species. *Sphinx canadensis* is included in the key because they have been taken in Arkansas although the authors have no specific data on them.

TABLE II. Sphingidae. Moths taken in Arkansas as indicated from other sources.

SPECIES	SOURCE*	TOTAL COLLECTED	DATE
<i>Aellopos titan</i>	RH ₁	1	June 14, 1958
<i>Aellopos fadus</i>	P ¹	1	Sept. 20, 1969
<i>Amphion nessus</i>	ASU	1	April 16, 1970
<i>Darapsa versicolor</i>	RH ₂	1	July 23, 1966
<i>Erinnyis ello</i>	P ²	1	Oct. 22, 1970
<i>Hemaris thysbe</i>	RH	6	April 20, 1969
<i>Isoparce cupressi</i>	F	-	----
<i>Manduca rustica</i>	ASU	1	Oct. 9, 1969
<i>Proserpinus juanita</i>	RH ₃	1	June 10, 1967
<i>Sphinx gordius</i>	F	-	----
<i>Sphinx kalmiae</i>	RH ₄	2	May 3, 1969

TABLE III. Sphingidae. Moths taken in adjacent states as indicated from other sources. Could occur in Arkansas.

SPECIES	SOURCE*	TOTAL COLLECTED	DATE
<i>Hyles gallii</i>	EN ₁	1	1913
<i>Erinnyis ello</i>	R&W	263	1954
<i>Eumorpha labruscae</i>	CU	1	None
<i>Eumorpha vitis</i>	EN ₃	1	1913
<i>Lapara coniferarum</i>	EN ₂	1	1898
<i>Faonias astylus</i>	T ²	4	1964
<i>Sphinx canadensis</i>	RH ₅	1	June 6, 1969
<i>Sphinx eremitus</i>	WTF	-	----
<i>Sphinx frankii</i>	WTF	-	----
<i>Sphinx vashti</i>	RH ₆	1	May 26, 1962

TABLE III. (Continued)

ASU	Arkansas State University Collection
CU	Columbia University, Missouri, Collection
EN ₁	Ent. News 24:460; Recorded in St. Louis, Missouri
EN ₂	Ent. News 9:190; Recorded from Southern Missouri
EN ₃	Ent. News 24:460; Recorded in St. Louis, Missouri
F	Freeman (1938); Recorded in Arkansas
P	Paulissen (1971); Recorded in Washington County, Arkansas
RH	Heitzman (1971); Recorded in Arkansas
RH ₁	Heitzman (1971); Recorded in Washington County, Arkansas
RH ₂	Heitzman (1971); Recorded in Madison County, Arkansas
RH ₃	Heitzman (1971); Collected larva in Washington County, Arkansas
RH ₄	Heitzman (1971); Recorded in Madison County, Arkansas
RH ₅	Heitzman (1971); Recorded in Warsaw & Benton County, Missouri
RH ₆	Heitzman (1971); Recorded in Jackson County, Missouri
R&W	Riherd and Wene (1955); Recorded at Weslaco, Texas
T	Taylor and Taylor (1965); Recorded in Southern, Mississippi
WTF	Forbes (1948); Indicated possible occurrence in Arkansas

KEY TO THE ADULTS

1.	Abdomen with pink lateral spots <i>Agrius cingulatus</i> Abdomen with only one entire segment white <i>Aellopos titan</i> Abdomen not as above 2
2.	Abdomen with bright yellow lateral spots 3 Abdomen without yellow spots 5
3.	Three lateral spots <i>Manduca rustica</i> Four or five lateral spots 4
4.	First yellow spot covered with white hairs; the three inner black stripes on hind wing well separated, with white between <i>Manduca quinquemaculata</i> First yellow spot almost free of white hairs; the two middle black stripes on hind wing partially fused <i>Manduca sexta</i>
5.	Fore wing angulate or scalloped along outer margin (Fig. 3) 6 Fore wing falcate or normal, at most with a slight tooth on Cu ₁ 14

6.	Fore wing outer margin regularly scalloped (Fig. 3-A, B, C, D) 7 Fore wing outer margin irregularly scalloped or angulate (Fig. 3-E, F, G, H) 10
7.	Hind wing has black "eyespot" with blue center, pink to red around "eyespot" <i>Paonias excaecatus</i> Hind wing without distinct "eyespot" 8
8.	Hind wing straw color to wood brown and somewhat matching the color of fore wing <i>Cressonia juglandis</i> Hind wing with rose or orangish color 9
9.	Hind wing with some bright pink to rose and a blackish diffuse triangular spot at anal angle; wingspread 4-5 inches <i>Pachysphinx modesta</i> Hind wing bright orange with some brown bordering; fore wing dark brown to gray <i>Erinnyis obscura</i> Vaguely scalloped similar to <i>E. obscura</i> , but abdomen with black lateral bars <i>Erinnyis ello</i>
10.	Hind wing with distinct "eyespot" 11 Hind wing without distinct "eyespot" 12
11.	Yellow around "eyespot" <i>Paonias myops</i> Reddish around "eyespot" <i>Smerinthus jamaicensis</i>
12.	Hind wing evenly tawny and lighter than fore wing; abdomen with dark brown subdorsal spots <i>Deidamia inscripta</i> Hind wing deep red to bright yellow on basal portion 13
13.	Abdomen with one or two bright yellow stripes <i>Amphion nessus</i> Abdomen with fifth segment lighter in color and light dorsal patches on segments six and/or seven; fore wing only vaguely scalloped at anal angle; base of hind wing tawny <i>Proserpinus juanita</i> Abdomen concolorous, outer margin of forewing distinctly scalloped (Fig. 3-F) base of hind wing yellow <i>Sphecodina abbottii</i>
14.	Wings largely transparent 15 Wings fully scaled 16
15.	Scaled part of fore wing deep red-brown <i>Hemaris thysbe</i> Scaled part of fore wing blackish .. <i>Hemaris diffinis</i>
16.	Hind wing distinctly tawny or marked extensively with pink 17 Hind wing not as above (except <i>E. pandorus</i> may have a little pink) 22

Charles L. Selman and Harvey E. Barton

17. Hind wing tawny 18
Hind wing with pink 20
18. Abdomen with black lateral bars;
fore wing pale gray with longitudinal
blackish streak **Erinnyis ello**
Abdomen with fifth segment lighter in color
and light dorsal patches or segments
six and/or seven **Proserpinus juanita**
Abdomen not as above 19
19. Fore tibiae finely spinulate (Fig. 4-A);
darker parts of fore wing dull reddish
brown, line from costa to inner margin
separating dark from light area, approxi-
mately midway, relatively
straight **Darapsa pholus**
Fore tibiae not spinulate; darker parts of
fore wing olive, line from costa to
inner margin separating dark from light
area, approximately midway, distinctly
not straight and almost broken in the
middle **Darapsa myron**
20. Hind wing pink border and inner margin;
cream colored stripe on fore wing forms
a 'Y' open to inner margin with anterior
arm of 'Y' about twice as long
as other **Eumorpha fasciatus**
Hind wing with a broad pink stripe or shade
on median area 21
21. A cream colored stripe from near base to
apex of fore wing **Hyles lineata**
No such stripe; a square spot on middle of
inner margin and a black dot near base
of fore wing **Eumorpha achemon**
22. Hind wing with pale yellow subterminal
wedges running together at anal angle;
on abdomen lateral and ventral sides
yellowish and dorsal side
brown **Xylophanes tersa**
Hind wing not as above 23
23. Fore wing olive green, broadly shaded,
and Cu₁ and Cu₂ with pink or flesh-
colored; hind wing with a large black
spot between base and anal
angle **Eumorpha pandorus**
Fore wing not in broad shades of olive green 24
24. Terminal long spur of hind tibia as long as
metatarsus (Fig. 4-B); discal white dot
on fore wing with black stalk pointing
toward outer margin **Paratreia plebeja**
Tibial spurs shorter 25
25. Fore tibiae finely spinulated; (check closely
because scales may cover spines)
(Fig. 4-A) 26
Fore tibiae not spinulate 32
26. Hind wing mostly diffuse brown to blackish,
not contrasting; fore wing dull brown,
shaded with yellowish
green **Ceratomia hageni**
Hind wing contrastingly marked with white or
very pale gray 27
27. Discal spot whitish 28
Discal spot black or obscure 29
28. Hind wing with black spot at base and
very contrasting inner white
band **Sphinx eremitus**
Hind wing grayish at base and inner band
diffuse but contrasting **Sphinx gordius**
29. Fore wing blackish, with costa and outer
margin whitish **Sphinx drupiferarum**
Fore wing not as above 30
30. Fore wing wood-brown; tegulae with inner
half striped with three black and two
wood-brown lines, and outer half
contrasting pale **Sphinx kalmita**
Tegulae not marked as above 31
31. Fore wing with black streak between veins
M₂ and M₃ **Sphinx canadensis**
Fore wing with the black streak missing from
between veins M₂ and M₃ **Sphinx chersis**
32. Hind wing mostly blackish and without
distinct lines or shades; fore wing with
strong dash from lower angle of cell to
outer margin below
middle **Manduca jasminearum**
Hind wing with distinct lines or shades 33
33. Abdomen with both subdorsal and lateral
series of white spots; under
2½ inches **Dolba hyloeus**
Abdomen not as above; wingspread over
2½ inches 34
34. Outer margin of fore wing concave at
Cu₁, costa contrastingly
paler **Ceratomia amyntor**
Outer margin of fore wing evenly curved 35
35. Fore wing with clear black dashes between
M₃ and Cu₂ postmedially; sacculus of
right valve with spur-like projection
on ventral side pointing posteriorly
(Fig. 4-D) **Ceratomia undulosa**
Fore wing with clear dashes toward apex,
but none below middle of wing;
sacculus of right valve not as above
(Fig. 4-C) **Ceratomia catalpae**

INSTITUTIONAL MEMBERS

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

Arkansas College
Batesville

Arkansas Polytechnic College
Russellville

Arkansas State University
State University

College of the Ozarks
Clarksville

Harding College
Searcy

Hendrix College
Conway

Ouachita Baptist University
Arkadelphia

Southern State College
Magnolia

State College of Arkansas
Conway

University of Arkansas
Fayetteville

Westark Junior College
Fort Smith

INDUSTRIAL MEMBERS

The following organizations in the state of Arkansas contribute to and make possible the ongoing educational efforts of the Arkansas Academy of Science through their Industrial Memberships.

Murphy Oil Company
El Dorado

The Relative Abundance, Seasonal Distribution and Taxonomy of Spingidae of Northeast Arkansas

BRIEF DESCRIPTION OF SPECIES WITH EMPHASIS
ON SIMILAR SPECIES

If moths can be determined from key alone, it does not seem advisable to include complete descriptions of the species as originally published or that can be obtained from the works listed in our introduction. In case complete descriptions are needed, they may be obtained from the references cited. Good descriptions of the family are given by Borror and White (1970), Forbes (1948), and Hodges (1971). However, as an aid, we have noted similar species as well as their diagnostic characters.

The terminology used in the literature for the parts of the male genitalia is not consistent; therefore, the terminology of Beirne (1942) has been adopted. Also, the terminology, as well as some descriptions, has been taken from Forbes (1948). Nomenclature is consistent with Hodges (1971).

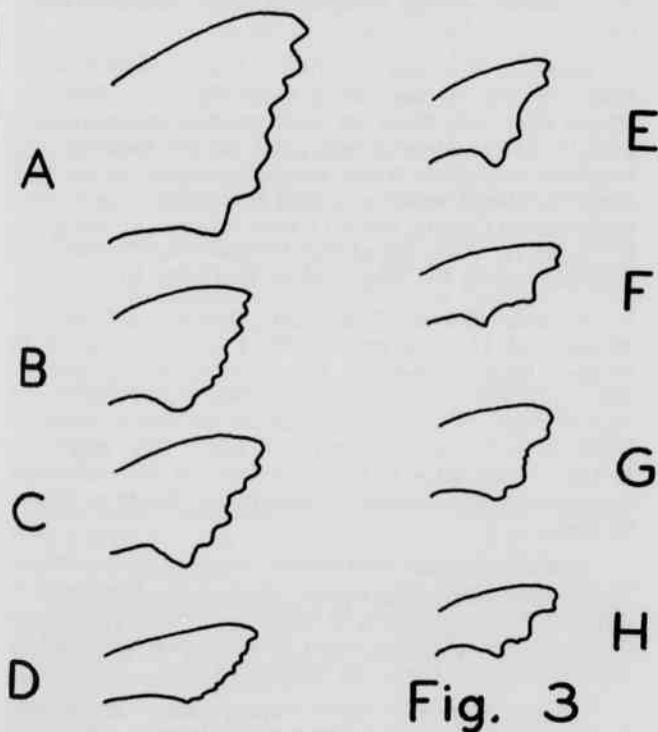


Figure 3 — Outer Margin of fore wing.

- A. *Pachysphinx modesta*
- B. *Cressonia juglandis*
- C. *Paonias excaecatus*
- D. *Erinnyis obscura* (*Erinnyis ello* is somewhat similar)
- E. *Paonias myops*
- F. *Sphecodina abbottii* (*Amphion nessus* is somewhat similar)

- G. *Smerinthus jamaicensis*
- H. *Deidamia inscripta* (*Amphion nessus* is somewhat similar)

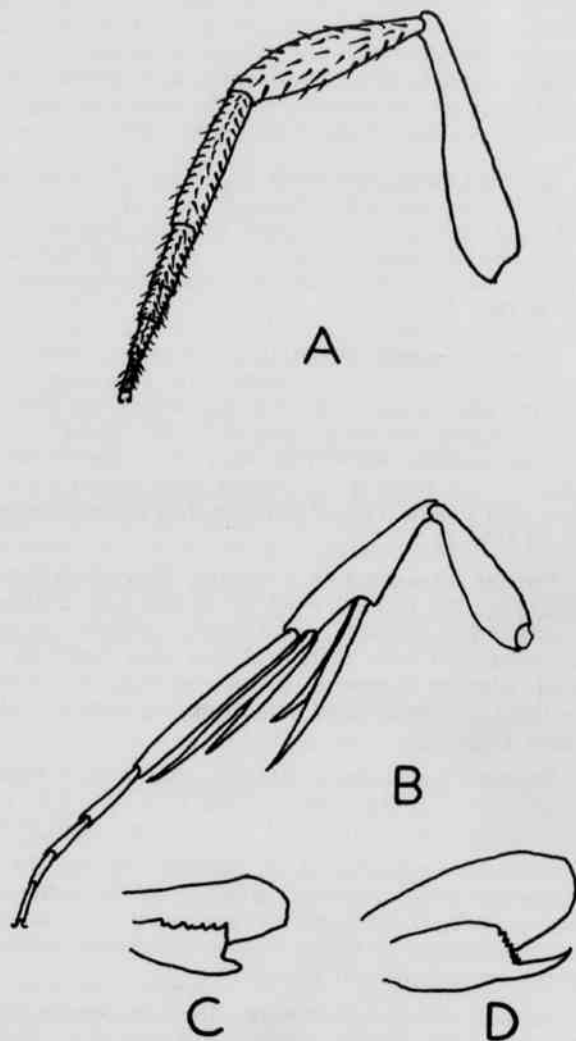


Figure 4

- A. Fore leg of *Ceratomia hageni* (*Darapsa pholus* is somewhat similar in spinulation)
- B. Hind leg of *Paratreia plebeja*
- C. Right valve of *Ceratomia catalpae*
- D. Right valve of *Ceratomia undulosa*

Agrius cingulatus (Fabricius). Pink-spotted Hawk-Moth. Wingspread $3\frac{1}{2}$ - $4\frac{1}{2}$ inches. Plate I: 1. Active from September 8 to October 30 (Table I), with greatest activity during the fourth week of October (Fig. 2).

Manduca rustica (Fabricius). Rustic Sphinx. Wingspread 4-5 inches. Plate I: 5. Recorded from Craighead County, Arkansas (Table II). Similar to *M. sexta* and *M. quinquemaculata*, but the three lateral yellow, black-ringed spots on each side of the abdomen and very contrasting fore wing will distinguish this moth.

Manduca quinquemaculata (Haworth). Tomato Hornworm. Wingspread 3-5 inches. Plate I: 13. Fore wing light gray, dull brown in center of wing. Similar to *M. rustica* and *M. sexta*. Active from June 1 to October 1 (Table I), with greatest activity during the first week of August (Fig. 2).

Manduca sexta (Linnaeus). Tobacco Hornworm. Wingspread $3\frac{1}{2}$ - 5 inches. Plate I: 14. Fore wing darker gray, the black scales dominant, and lines more uniformly wavy across the wing. Similar to *M. rustica* and *M. quinquemaculata*. Active from May 27 to September 12 (Table). While there is no definite peak shown, most of these moths were trapped between July 22 and September 12 (Fig. 2).

Paonias excaecatus (J. E. Smith). Blind-Eyed Sphinx. Wingspread 2-3 inches. Plate III: 2; Fig. 3-C. Similar to *S. jamaicensis*, but with only a single "eyespot" on each hind wing, and outer margin of fore wing distinctly different. Also see *P. myops*. Active from May 28 to August 20 (Table I), with greatest activity during second week of August (Fig. 1).

Pachysphinx modesta (Harris). Big Poplar Sphinx. Wingspread $3\frac{1}{2}$ - $5\frac{1}{2}$ inches. Plate II: 1; Fig. 3-A. Only one specimen from Craighead County, none from Fulton.

Cressonia juglandis (J. E. Smith). Walnut Sphinx. Wingspread $1\frac{1}{2}$ - 3 inches. Plate II: 9; Fig. 3-B. Hind wing somewhat scalloped as fore wing. Active from May 4 to August 29 (Table I), with greatest activity during the second week of August (Fig. 1).

Erinnyis obscura (Fabricius). Obscure Sphinx. Wingspread 2 - $2\frac{1}{2}$ inches. Plate II: 14, Fig. 3-D. Similar to *E. ello*, but the fore wings are darker and size smaller with *E. obscura*. Only one specimen taken from Craighead County, none from Fulton (Table I).

Paonias myops (J. E. Smith). Small-Eyed Sphinx. Wingspread 2 - $2\frac{1}{2}$ inches. Plate III: 7; Fig. 3-E. Similar to *P. excaecatus* and *S. jamaicensis*, but can be distinguished by its bright yellow area around the "eyespot" in the hind wing. Active from April 24 to September 1 (Table I), with greatest activity during the last week of August (Fig. 2).

Smerinthus jamaicensis (Drury). Twin-Spotted Sphinx. Wingspread $2\frac{1}{2}$ - 3 inches. Plate I: 11; Fig. 3-G.

Similar to *P. myops* and *P. excaecatus*. Thorax with a large deep-brown central patch. Fore wing pale gray and brown, with a strongly angled chocolate brown antemedial band, from which a dash extends out along Cu_2 . Usually with two blue bars in each "eyespot", but can have three or only one. Active from May 5 to September 4 (Table I), greatest activity near the end of August (Fig. 1).

Sphecodina abbottii (Swainson). Abbot's Sphinx. Wingspread $2\frac{1}{4}$ - 3 inches. Plate III: 3; Fig. 3-F. Similar to *A. nessus*, but can be separated by the lack of yellow stripes on abdomen. Active from April 22 to April 30 (Table I).

Amphion nessus (Cramer). Nessus Sphinx. Wingspread $1\frac{3}{4}$ - 2 inches. Plate I: 8; Fig. 3-F, H. Similar to *S. abbottii*. Body and fore wing dull brown. Hind wing rusty brown with a broad black border. Two bright yellow stripes across the abdomen. This is a day flying moth. Recorded from Craighead County, Arkansas (Table II).

Deidamia inscripta (Harris). Lettered Sphinx. Wingspread 2 - $2\frac{1}{4}$ inches. Plate I: 12; Fig. 3-H. Fore wing toward base with about six dark shade-lines arranged in pairs and fusing into a dark patch on the inner margin. Abdomen with dark brown subdorsal spots. Active from April 9 to May 8, however, only 4 specimens were trapped in Craighead County, while 12 were taken in Fulton County (Table I). Also, 10 of the 16 specimens taken were recorded during the first week of May (Fig. 2).

Hemaris diffinis (Boisduval). Snowberry Clearwing. Wingspread $1\frac{1}{4}$ - 2 inches. Plate I: 6. Similar to *H. thysbe*. Body loose-hairy, closely mimicking a bumblebee. Fore and hind wings almost free of any scales and mostly clear. There are a number of forms, most of which are described by Forbes (1948). The specimens in Table I were taken in Fulton County and do not indicate any seasonal distribution or abundance. Feeds at flowers by day.

Hemaris thysbe (Fabricius). Humming-Bird Moth. Wingspread $1\frac{1}{4}$ - $2\frac{1}{4}$ inches. Plate I: 7. Similar to *H. diffinis*. Thorax and base of wings deep red-brown. There are a number of forms, most of which are described by Forbes (1948). Feeds at flowers by day.

Darapsa pholus (Cramer). Azalea Sphinx. Wingspread 2-3 inches. Plate III: 1. Similar to *D. myron*, but can be separated by the finely spinulate fore tibiae (Fig. 4-A). Underside dull reddish tawny with much grayer margin. Active from April 22 to May 14 (Table I). Of the 10 specimens recorded, 4 were from Craighead County and 6 were from Fulton County. The activity was greatest near the end of April (Fig. 2).

Erinnyis ello (Linnaeus). Ello Sphinx. Wingspread 3-4 inches. Plate II: 4; Fig. 3-D. Similar to *E. obscura*. Females lack the black streak in fore wing. Should occur in Arkansas (Table II & III).

Proserpinus juanita (Strecker). Juanita Sphinx. Wingspread 2 inches. Plate I: 10. Burton and Drew (1967) states that fore wings with shades of light brown to dark gray; wide dark transverse band in median area; basal portions of hind wings ranging from deep red to bright yellow with dark borders on outer margins; abdomen concolorous except for light colored fifth segment, light dorsal patches on segments six and seven. Recorded from Arkansas (Table II).

Darapsa myron (Cramer). Green Grape-Vine Sphinx. Wingspread 2 - 3 inches. Plate III: 4. Similar to *D. pholus*. Underside of fore wing tawny, shading to dull greenish toward margins; hind wing much duller. Also, fore tibiae unarmed. Active from May 5 to September 2 (Table I), with activity peaks near June 10 and July 29. However, this moth was active a number of times during this period (Fig. 1).

Eumorpha fasciatus (Sulzer). Lesser Vine Sphinx. Wingspread 3 - 4½ inches. Plate II: 10. Similar to *H. lineata*, but can readily be distinguished by the plate. This a tropical species that strays north into many states.

Hyles lineata (Fabricius). White-Lined Sphinx. Wingspread 2 - 3½ inches. Plate III: 5. Similar to *E. fasciatus*. All of our specimens were taken at night but they often fly by day. Active from May 7 to October 5 (Table I), with activity varying greatly over this period (Fig. 1).

Eumorpha achemon (Drury). Achemon Sphinx. Wingspread 3 - 4 inches. Plate I: 17. Similar to *E. pandorus*, but can be immediately separated by the hind wing which is more than one-half pink. Active from July 1 to August 12 (Table I).

Xylophanes tersa (Linnaeus). Texas Sphinx. Wingspread 2½ - 3 inches. Plate III: 6. Active from May 10 to October 27 (Table I), with variable activity all summer (Fig. 2).

Eumorpha pandorus (Hubner). Pandora Sphinx. Wingspread 3 - 4½ inches. Plate I: 2. Similar to *E. achemon*. Active from July 8 to October 1 (Table I).

Paratreia plebeja (Fabricius). Plebeian Sphinx. Wingspread 2½ - 3 inches. Plate II: 6. Similar to *C. catalpae*, *C. undulosa*, *C. hageni*, and *M. jasminearum*; however, it can quickly be distinguished by the long spine of hind tibia being as long as metatarsus. Active from May 6 to August 31 (Table I), with greatest activity during the first week of July (Fig. 1).

Ceratomia hageni Grote. Hagens Sphinx. Wingspread 3-4 inches. Plate II: 11. Similar to *C. catalpae*, *C. undulosa*, and *M. jasminearum*, but it is easily separated by its finely spinulate fore tibiae (Fig. 4-A). Also see *P. plebeja*. Active from April 16 to September 3 (Table I), with peak activity first two weeks of July (Fig. 2).

Sphinx chersis (Hubner). Great Ash Sphinx. Wingspread 3½ - 4½ inches. Plate I: 3. Similar to *S. drupiferarum*, *C. amyntor*, *S. kalmiae*, *S. canadensis*, *S. gori-*

us, and *S. eremitus*. Unique distinguishing characters for each are as follows: *S. chersis* has obscure discal spot and missing black streak between M_2 and M_3 ; *S. canadensis* has obscure discal spot but has a black streak between M_2 and M_3 ; *S. kalmiae* has dark brown discal spot (somewhat 4 pointed) and fore wing light wood brown; *S. drupiferarum* has narrow, black discal spot but fore wing blackish; *S. gordius* has white contrasting discal spot and base of hind wing grayish; *S. eremitus* has pale to white discal spot and base of hind wing black; *C. amyntor* has pale to obscure discal spot and fore wing is wood brown with costa contrastingly paler. The only specimen collected came from the Fulton County trap on August 10 (Table I), however, Heitzman (1971) states that this has been a very common moth in past years.

Sphinx drupiferarum J. E. Smith. Wild-Cherry Sphinx. Wingspread 3 - 4½ inches. Plate I: 16. For similar species see *S. chersis*. The only specimen collected came from Fulton County on May 8 (Table I).

Sphinx kalmiae J. E. Smith. Laurel Sphinx. Wingspread 3½ inches. Plate I: 15. For similar species see *S. chersis*. Recorded from Arkansas (Table II).

Sphinx canadensis Boisduval. Canada Sphinx. Wingspread 3¼ inches. Plate I: 4. For similar species see *S. chersis*. Should occur in Arkansas (Table III).

Sphinx gordius Cramer. Apple Sphinx. Wingspread 3 - 3½ inches. Plate II: 13. For similar species see *S. chersis*. Recorded from Arkansas (Table II).

Sphinx eremitus (Hubner). Hermit Sphinx. Wingspread 3 inches. Plate II: 8. For similar species see *S. chersis*. Should occur in Arkansas (Table III).

Manduca jasminearum (Guerin). Jessamine Sphinx. Wingspread 3 - 4½ inches. Plate II: 2. Similar to *C. catalpae*, *C. undulosa*, *P. plebeja*, and *C. hageni*, however the heavy black bar beyond middle of wing above M_3 and a shorter one below it will distinguish this moth. The two specimens collected came from the Fulton County trap (Table I).

Ceratomia amyntor (Geyer). Four-Horned Sphinx. Wingspread 3 - 4½ inches. Plate II: 7. For similar species see *S. chersis*. The only specimen collected came from Fulton County on May 28 (Table I).

Ceratomia undulosa (Walker). Waved Sphinx. Wingspread 3 - 4½ inches. Plate II: 3. Check genitalia (Fig. 4-D). For similar species see *M. Jasminearum*. Active from May 15 to September 3 (Table I), with greatest activity during the second week of July (Fig. 1).

Ceratomia catalpae (Boisduval). Catalpa Sphinx. Wingspread 2½ to 3½ inches. Plate II: 12. Check genitalia (Fig. 4-C). For similar species see *M. Jasminearum*. Active from May 6 to September 10 (Table I). This moth was very active from the middle of July through September 9 (Fig. 1).

Dolba hyloeus (Drury). Pawpaw Sphinx. Wingspread $1\frac{1}{2}$ - 3 inches. Plate II: 5. Hind wing brown-black, with a white patch at base and postmedian band, the latter more or less double toward anal angle and connected to the white base along the costa. This one specimen was taken at dusk in Fulton County on September 10 (Table I).

Aellopos titan (Cramer). Titan Sphinx. Wingspread 2 inches. Plate I: 9. Hodges (1971) states that *A. titan* very closely resembles *A. fadus* (Table II), which has also been recorded from Arkansas, but *A. titan* may be recognized by having a black spot at the end of the cell of the fore wing which is lacking in *fadus*. Superficially *titan* and *fadus* look very much the same. Recorded from Arkansas (Table II).

FOLLOWING ARE SPHINGIDAE, NOT CONTAINED IN OUR KEY, THAT COULD OCCUR IN ARKANSAS:

<i>Aellopos fadus</i>	Table II
<i>Darapsa versicolor</i>	Table II
<i>Erinnyis ello</i>	Table II
<i>Eumorpha labruscae</i>	Table III
<i>Eumorpha vitis</i>	Table III
<i>Hyles gallii</i>	Table III
<i>Lapara coniferarum</i>	Table III
<i>Paonias astylus</i>	Table III
<i>Sphinx frankii</i>	Table III
<i>Sphinx vashti</i>	Table III

PLATE I

(All figures approximately $\frac{1}{2}$ natural size)

1. *Agrius cingulatus*
2. *Eumorpha pandorus*
3. *Sphinx chersis*
4. *Sphinx canadensis*
5. *Manduca rustica*
6. *Hemaris diffinis*
7. *Hemaris thysbe*
8. *Amphion nessus*
9. *Aellopos titan*
10. *Proserpinus juanita*
11. *Smerinthus jamaicensis*
12. *Deidamia inscripta*
13. *Manduca quinquemaculata*
14. *Manduca sexta*
15. *Sphinx kalmiae*
16. *Sphinx drupiferarum*
17. *Eumorpha achemon*



PLATE II

(All figures approximately 1/2 natural size)

1. *Pachysphinx modesta*
2. *Manduca jasminearum*
3. *Ceratomia undulosa*
4. *Erinnyis ello*
5. *Dolba hyloeus*
6. *Paratreia plebeja*
7. *Ceratomia amyntor*
8. *Sphinx eremitus*
9. *Cressonia juglandis*
10. *Eumorpha fasciatus*
11. *Ceratomia hageni*
12. *Ceratomia catalpae*
13. *Sphinx gordius*
14. *Erinnyis obscura*

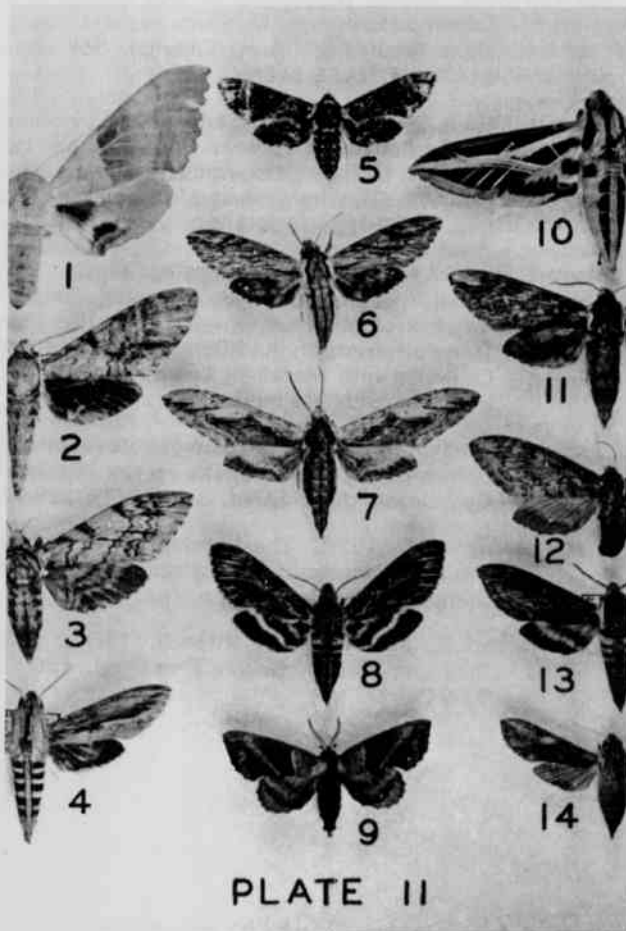


PLATE II

PLATE III

(All figures approximately 1/2 natural size)

1. *Darapsa pholus*
2. *Paonias excaecatus*
3. *Sphecodina abbottii*
4. *Darapsa myron*
5. *Hyles lineata*
6. *Xylophanes tersa*
7. *Paonias myops*

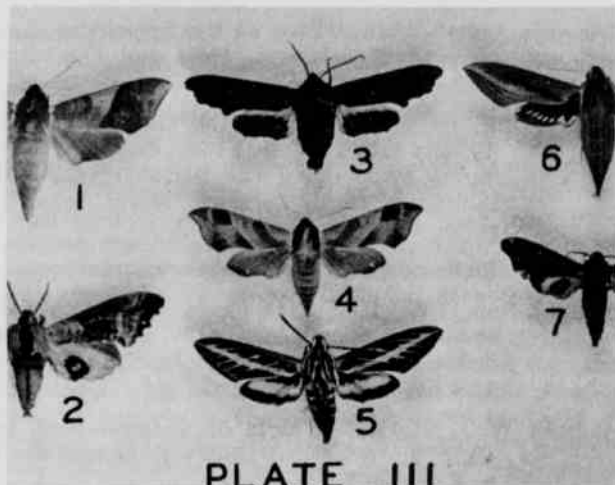


PLATE III

ACKNOWLEDGEMENTS

We would like to express our appreciation for the help in the maintenance of the traps to Dr. Richard Mitchell of Arkansas State University and to Wilbur Mitchner of Mammoth Spring, Arkansas. We are also indebted to Dr. James Hutchison of Arkansas State University for photographic work. A special thanks to Richard Heitzman of Independence, Missouri for his loan of specimens, constant help with identification, and for his critical reading of the manuscript.

REFERENCES CITED

- Beebe, R. 1952. Sampling Michigan Lepidoptera by the Fixed Light Trap. *Lepidopterists News*: 7(7): p. 28.
- Beirne, B. P. 1942. The Morphology of the Male Genitalia of the Lepidoptera. *Entomol. Record*. 54: pp. 16-22.
- Borror, Donald J. and R. E. White. 1970. *Field Guide to the Insects of America North of Mexico*. Houghton Mifflin Co. pp. 404.

Charles L. Selman and Harvey E. Barton

- Burton, Robert and Wm. A. Drew. 1967. The Sphinx Moths of Oklahoma. Proc. of the Okla. Acad. of Sci. 48: pp. 16-22.
- Bucher, G. E. 1967. Pathogens of Tobacco and Tomato Hornworms. Jour. Invert. Path. 9(1): pp. 82-89.
- Coop. Econ. Ins. Rpt. 1966. Blacklight Trap Standards for General Insect Surveys. 16(14):297.
- Forbes, Wm. T. M. 1948. Lepidoptera of New York and Neighboring States, Part II. Cornell Univ. Agr. Exp. Sta. Mem., 274: 176-202.
- Freeman, Avery. 1938. Notes on the Sphingidae (Lepidoptera) of Arkansas. Field and Laboratory, 6:33-43, Fig. 1-3.
- Gentry, C. R. and F. R. Lawson, C. M. Knott, J. M. Stanley, and J. J. Lam, Jr. 1967. Control of Hornworms by Trapping with Blacklight and Stalk Cutting in North Carolina. Journ. Econ. Entomol. 60(5): pp. 1437-1442.
- Heitzman, Richard. 1971. Personal Communication.
- Hodges, Ronald W. 1971. The Moths of America North of Mexico, Sphingoidea. E. W. Classey Limited and R. B. D. Publ. Inc. Fascicle 21:xii + 158 pages, 14 Pl.
- Holland, W. J. 1903. The Moth Book. Dover Publ. Inc. pp. 479. (Reprinted 1968 with annotations by A. E. Brower).
- Kimball, C. P. 1965. Lepidoptera of Florida. Fla. Dept. Agr. pp. 363 (pp 59-68).
- Klots, A. B. 1951. Field Guide to the Butterflies of North America. Houghton Mifflin Co. pp. 349.
- McDunnough J. 1938. Check List of Lepidoptera of Canada and the United States. Part I. Macrolepidoptera of Canada Mem. Southern Calif. Acad. Sci. I: pp. 275.
- McFadden, M. W. 1969. Successful Laboratory Mating of *Apanteles congregatus*, Parasite of the Tobacco Hornworm, *Manduca sexta*. Ann. Entomol. Soc. Amer. 62(2): pp. 342-344.
- McFadden, M. W., and J. J. Lam, Jr. 1968. Influence of Population Level and Trap Spacing on Capture of Tobacco Hornworms Moths in Blacklight Traps with Virgin Females Journ. Econ. Entomol. 61(5): pp. 1150-1152.
- Paulissen, Leo. 1971. Personal Communication.
- Riherd, P. T. and G. P. Wene. 1955. A Study of Moths Captured at a Light Trap at Weslaco, Texas. Jour. Kansas Entomol. Soc. 28(3): pp. 102-107.
- Rouse, E. P. 1965. The Swallowtail Butterflies of Arkansas. Ark. Acad. Sci. Proc. 19: pp. 37-39.
- . 1968. The Satyrs and Wood Nymphs of Arkansas. Ark. Acad. Sci. Proc. 22: pp. 29-31.
- . 1969. The Pieridae of Arkansas. Ark. Acad. Sci. Proc. 23: pp. 94-104.
- . 1970. The Butterflies of Arkansas Family Nymphalidae. Ark. Acad. Sci. Proc. 24:
- Sparks, M. R. 1968. Responses of Two Strains of the Tobacco Hornworm, *Manduca sexta*, to Various Light Intensities. Ann. Entomol. Soc. Amer. 61(6): pp. 1466-1468.
- Stewart, Paul A., Jesse J. Lam, Jr. and J. David Hoffman. 1967. Activity of Tobacco Hornworm and Corn Earworm Moths as Determined by Traps Equipped with Blacklight Lamps. Jour. Econ. Entomol. 60(6): pp. 1520-1522.
- Stewart, Paul A., Cecil R. Gentry, Crawford M. Knott, and Jesse J. Lam, Jr. 1968. Seasonal Trends in Catches of Moths of the Tobacco Hornworm, Tomato Hornworm, and Corn Earworm in Traps Equipped with Blacklight Lamps in North Carolina. Jour. Econ. Entomol. 61(1): pp. 43-46.
- Taylor, Robert and Barbara Taylor. 1965. Collecting Sphingids and Other Moths on the Mississippi Gulf Coast. Jour. Lepid. Soc. 19(3): 189-190.
- Tietz, Harrison M. 1952. The Lepidoptera of Pennsylvania. A Manual. Pennsylvania State Univ., State College, Pa. 194 pp. (pp. 23-30).
- Zim, Herbert S., and Robert T. Mitchell. 1964. Butterflies and Moths. Golden Press. pp. 160 (pp. 81-94).

Phosphorescent Animal Forms of Arkansas

Peggy Rae Dorris

Department of Biology, Henderson State College

Arkadelphia, Arkansas 71923

ABSTRACT

Two phosphorescent animal forms, *Euryurus* sp. and *Centruroides vittatus*, were collected with a black light in an attempt to collect phosphorescent spiders. Both the millipede and the scorpion were easily observed by the bright phosphorescent yellow color which glowed in the presence of the black light.

Throughout the ages man has been fascinated with phosphorescent and bioluminescent forms, but presently there are no records of research concerning phosphorescent forms in Arkansas. In an attempt to determine whether some spiders are phosphorescent this writer discovered two relatives of spiders which were highly phosphorescent. No phosphorescent spiders have been collected by this writer at the present time but it is believed that such forms exist and continuing efforts are being made to find these individuals. Indebtedness is expressed to Henderson State College for providing financial aid for this and other research projects on the arachnids which are presently being investigated.

A common safari light which had the original fluorescent tube replaced with a black light tube was used at night over various areas of the state. When the light was held about two feet from the ground, trees, and other similar objects; phosphorescent forms, when present, were immediately recognized. Of all black lights tried, this appeared to be the most inexpensive, convenient, and dependable for field work.

Millipedes of the genus *Euryurus* were collected over wide areas of Arkansas. Identification to species is pending. These specimens appear bright yellow under the

black light and can be found in large numbers during the late summer and early autumn. The body is broad and flat with 17 segments. Dorsal plates are without transverse furrows and the basal segments of the legs are without spines. The anal segment is blunt or rounded with the posterior edges of segments and lateral plates orange. There is also a black line present on the mid-dorsal surface. Members of *Euryurus* were most often collected from the grasses where decaying leaves had aggregated; however in some instances they appeared to be migrating in numbers from one area to another. They are apparently very active at night.

The striped scorpion, *Centruroides vittatus* was also collected in large numbers over the state but the greatest numbers were found in the more western countries of Arkansas. The bright yellow color with the dark stripe is quite easily observed when a black light is shined on specimens. Most of the scorpions were collected around sandy areas under rocks, bark, and other similar habitats.

This paper is a record of preliminary research of phosphorescent forms in Arkansas. The study is being continued and this report is by no means intended as a definitive work.

A Pre- Impoundment Limnological Study of the Strawberry River In Northeastern Arkansas

Henry W. Robison¹ and George L. Harp

Division of Biology, Arkansas State University, State University, Arkansas 72467

ABSTRACT

A study of pre-impoundment limnological characteristics of the Strawberry River was made from August, 1967 to June, 1968. Two collecting stations were established, one upstream which would not be inundated and a lower station which would be inundated when impoundment was complete. The Strawberry River was characterized by high alkalinity and pH, low carbon dioxide and turbidity, and adequate oxygen values. Plankton was characterized by limited numbers of *Staurastrum*, *Gomphonema*, and Rotatoria. Pool-riffle communities were ill-defined. Chironomidae, Oligochaeta and Ephemeroptera were dominant pool macroinvertebrates among 13 taxa collected. Of the 20 taxa collected in riffles Trichoptera, Ephemeroptera, Simuliidae and Chironomidae were the most numerous. Longitudinal zonation was characterized by an increase in species and numbers of pool benthic macroinvertebrates from headwater to downstream areas. Numerical standing crop was recorded for pools on 8 June 1968 and riffles on 30 September 1967. A total of 1979 fishes constituting 49 species were taken in this study. Station I and II pools yielded 242 and 185 fishes/ha respectively, *Dorosoma cepedianum* and *Moxostoma erythrurum* being the dominant forms. The substantial populations of *Dorosoma cepedianum* seemingly are supported by debris and allochthonous materials and not on the sparse plankton present. Station I and II riffles yielded 2896 and 1108 fishes/ha respectively, *Etheostoma caeruleum* and *Percina caprodes* being most numerous. Longitudinal zonation was characterized by decrease in number/ha and species present from headwater to downstream areas.

The Ozark Mountains and their characteristic streams are one of the greatest assets of northeastern Arkansas. Their value in supporting a bass fishery is increasing yearly. One such Ozark stream is the Strawberry River, whose course will be dammed within the next few years as part of the White River Basin Project. The proposed dam site, river mile 26.2, is on the Bell Foley farm in Sharp County, Arkansas, eight km west of Smithville, Lawrence County.

This study was undertaken to describe the pre-impoundment conditions of the Strawberry River physiochemically and biotically; to provide a comparative basis for a post-impoundment study which would determine what changes, if any, result from this action; and to provide additional information on Ozark streams, a unique habitat which is poorly known.

DESCRIPTION OF THE AREA. The Strawberry River is a spring-fed, relatively clear stream consisting of many wide, shallow pools separated by riffles flowing primarily through limestone formations in northeastern Arkansas. It arises in Ordovician Calico sandstone of lower Fulton County and winds through Cotter dolomite in Izard and Sharp counties. Midway into Lawrence County the river passes through Powell limestone, then in rapid succession through Smithville and Black Rock limestone. As it nears its confluence with the Black River, the Strawberry River is bordered by Cretaceous Nacatoch sandstone near Saffel, Arkansas. Reaching its confluence with the Black River, the Strawberry River drops into Quaternary Alluvium (Croneis, 1930). Major soils adjacent to the river are chiefly of the Huntington and Elk series (Soil Conservation Service, 1964). Mean annual

rainfall is 112, 119, and 138 cm in Izard, Sharp and Lawrence Counties, respectively. Air temperatures ranges from -25 C to 40 C (Hickmon, 1941). No organic sewage is known to be dumped into the river.

MATERIALS AND METHODS. Two stations were established. The upper station, Station I, located above the proposed impoundment area at Horseshoe Bend, near Franklin, Izard County, Arkansas, S 20, T 18 N, R 7 W, will serve as a reference for post-impoundment investigations.

The lower station, Station II, located near Poughkeepsie, Sharp County, Arkansas, S 19, T 17 N, R 5 W, will be situated midway in the lake to be formed by the proposed dam. This station will allow a comparison with post-impoundment investigations.

Excluding fishes, limnological factors were determined on three occasions to provide a seasonal picture. Collections were made 30 September 1967, 20 January and 8 June 1968. Fishes were collected during the week of 7-11 August 1967.

PHYSICOCHEMICAL METHODS. On each occasion the following determinations were conducted in both pool and riffle areas, at each station. Dissolved oxygen was determined by the Sodium Azide modification of the Winkler Method (APHA, 1960). Analysis of alkalinity and carbon dioxide followed standard limnological procedures (Welch, 1948). A colorimetric pH meter was used to determine the hydrogen-ion (pH) concentration. The Secchi Disc and Jackson turbidimeter were used for determination of light penetration and turbidity. Surface and water temperatures were determined with a centigrade thermometer.

¹Present address: Southern State College, Magnolia, Ark.

BIOLOGICAL METHODS. Samples of rooted aquatic plants were collected and classified to species.

Plankton samples were procured by a Wisconsin net with a mesh of No. 25 silk bolting cloth. Sample size was 100 l and from the pool community only. Preservation was by 70% ethanol. Quantitative composition was determined by differential count (Welch, 1948).

Benthos was sampled at each station using the transect method to determine vertical distribution. On each collecting trip three bottom samples were collected from the pool at each station with a 15.2 cm² Ekman dredge. Similarly, three 0.93 m² samples were taken from the riffle of each station with the Surber sampler. Bottom samples were screened through a sieve of 11.8 sq/linear cm, preserved in 10% formalin, and later transferred to 70% ethanol. Keys by Pennak (1953) and Usinger (1963) were used in identification.

Fishes were taken by rotenone application and preserved in 10% formalin. Classification was according to Bailey et al. (1960), while Eddy (1957), Moore (1957), Hubbs and Lagler (1958) and Pflieger (1966) were used in identification.

RESULTS AND DISCUSSION. Physicochemical Characteristics. The Strawberry River was characterized by high pH, low carbon dioxide and turbidity, and adequate oxygen values (Tables 1, 2), which are typical of Ozark streams (Neel, 1951; Campbell and Funk, 1953; Reid, 1961; Van Kirk, 1962; Minshall and Minshall, 1966).

Physicochemical conditions in the pool and riffle areas showed only slight differences. There is no sharp demarcation of pool and riffle at either station.

Longitudinal zonation was characterized by a general increase in the amount of dissolved oxygen, alkalinity, and pH at the lower station (Tables 1, 2). The upper reaches of a spring-fed stream are typically lower in dissolved oxygen because ground waters fail to provide oxygen to the waters (Reid, 1961). The increase in alkalinity and pH at the lower station indicated that there was a change in the dissolved solids at stream junctions between the upper and lower stations. The watershed of Station I is primarily Ordovician Calico limestone, while the larger watershed of Station II encompasses Cotter dolomite, Powell, Smithville and Black Rock limestones (Croneis, 1930).

Dissolved carbon dioxide is kept low because it enters into combination with lime in the substrate to form carbonates (Reid, 1961) or is lost to the atmosphere through turbulence.

Light penetration values were generally greater at Station I than at Station II showing Station I to be less turbid on all trips. Turbidity values were less conclusive, and the Jackson Turbidimeter does not allow determinations below 25 ppm. On January 1968, however, with values above 25 ppm, Station I again proved to be the less turbid station. Low turbidity values are attributed

to the nature of the watershed and concomitant absence of organic pollution.

Seasonally the amount of dissolved oxygen and carbon dioxide was highest on 20 January 1968, a period of low temperature. Oxygen values were lowest on 8 June 1968, when water temperatures were highest.

Alkalinity and pH values were lowest on 20 January 1968 and highest on 8 June 1968. The week previous to 20 January was marked by a period of heavy rainfall resulting in excessive runoff. This probably introduced a dilution factor which lowered the alkalinity. Because the carbon dioxide was highest on this sample date, it follows that the pH would be lower because pH varies inversely with the dissolved carbon dioxide concentration and directly with the bicarbonate concentration (Reid, 1961).

Further indications of the flood conditions during 20 January 1968 were the highest turbidity and lowest light penetration values on that date.

BIOLOGICAL CHARACTERISTICS. Rooted aquatic plants were limited to *Justicia americana* (L) Vahl, which bordered the riffle at Station I and a single specimen of *Nuphar luteum* (L) Sibthorp & Smith found in the pool at Station I. No rooted aquatic plants were found at Station II. Although poor substrate and swift current limits the presence of rooted aquatic plants in Ozark streams (Sullivan, 1929; Sublette, 1949; Moore and Paden, 1950; Campbell and Funk, 1953; Van Kirk, 1962) the bed of *J. americana* probably provided protection for a limited population of benthic macroinvertebrates. During 7-11 August 1967, several darters were taken from this area.

The river was characterized by a paucity of plankton. For this reason, no patterns of longitudinal or seasonal nature emerged. Rotatoria was collected twice, *Staurastrum* and *Gomphonema* once each. Numbers varied from 49-103/l. These were the only taxa observed in differential counts, although *Ceratium* was also noted in random surveys. All are typical stream forms (Reid, 1961; Hanebrink, 1965). Streams normally support a small plankton population because of current (Reid, 1961).

The pool benthic macroinvertebrate communities of Strawberry River were qualitatively and quantitatively sparse, the dominant taxa being Chironomidae, Oligochaeta and Ephemeroptera, in that order (Table 3). A sand-bottom pool habitat characteristically has few indigenous macroinvertebrates and may never possess communities because of constant shifting (Gersbacher, 1937; Kendeigh, 1961). Chironomidae has previously been found to be the dominant pool form in Ozark-type streams (O'Connell and Campbell, 1953; Van Kirk, 1962; Aggus and Warren, 1965). That clear demarcation of pool-riffle communities is absent in the Strawberry River is suggested by the fact that Ephemeroptera such as *Sten-*

onema and *Isonychia* comprised the third largest taxon in the pool communities. These forms are adapted as vigorous swimmers (*Isonychia*) or for clinging (*Stenonema*) in swift water habitats.

The riffle communities of the Strawberry River supported greater numbers and diversity of benthic macrofauna than did the pools (Table 4). At Station II the macroinvertebrate pool community was composed of fewer taxa but more total organisms than the riffle community. There was no clear demarcation of pool-riffle at Station II, therefore the riffle community approached that of the pool. In general, the greater number and diversity of macroinvertebrates in riffles are correlated with more optimal conditions such as light, food (aufwuchs) and oxygen, as well as the greater diversity of microhabitats to be found here (Kendeigh, 1961). The dominant forms of macroinvertebrates included Trichoptera (*Cheumatopsyche* and *Chimarra*), Ephemeroptera (*Isonychia* and *Stenonema*) and Diptera (Chironomidae and Simuliidae), in that order.

Longitudinal zonation was characterized by an increase in species and numbers of the pool benthic macrofauna and a decrease in species and numbers of riffle benthic macrofauna from Station I to Station II. Armitage (1961) and Reid (1961) noted an increase in number of species of benthic macrofauna downstream correlated with increased microhabitat diversity. The data from the pool support this finding. The riffle data seem to disagree, however it must be remembered that the riffle at Station II is much less defined than the riffle at Station I, and there was a decrease in microhabitat diversity at Station II riffle.

Vertical distribution was uniform from one side to the other (Robison, 1968). Although the reason for this is not clear, it perhaps is correlated with a relatively uniform current velocity from stream bank to stream bank (Kendeigh, 1961).

A seasonal minimum for total benthic macrofauna of both stations was recorded on 20 January 1968, and a maximum for pool only on 8 June 1968 and for riffles on 30 September 1967. These figures agree with Needham (1938) and Stehr and Branson (1938) was found numerical maxima occurring in late summer and again in autumn. Winter flooding was apparently responsible for a seasonal minimum of total benthic macrofauna on 20 January 1968. Moffett (1936), Sublette (1949), Mathis (1965), and Aggus and Warren (1965) also observed a large reduction of benthic macrofauna following winter and spring floods. Because of the large decrease in biomass of benthos, floods probably have a more adverse effect than is generally known.

Fishes function as an intermediate link in the food chain between the benthos and man. Small forage fishes act as link between the benthos and larger fishes. Larger fishes, the predators, are the ultimate consumers in the aquatic community. The predominant predator in this study was *Micropterus punctulatus*. The most abundant

forage fishes were *Dorosoma cepedianum* and *Lepomis megalotis* (Table 5).

Stream fishes can usually be divided on the basis of pool and riffle forms because of habitat preference. This separation is not absolute because of their mobility. For example, pool forms often move into the riffles to feed or in migration to other pools. The dominant pool forms were *Dorosoma cepedianum*, *Moxostoma erythrurum* and *Lepomis megalotis* (Table 5). Reid (1961) and Van Kirk (1962) reported Cyprinidae, Centrarchidae and Catostomidae as dominant pool forms in similar streams. Pools have been reported as supporting a larger and more diverse fish population than riffles because the current is not a limiting factor in this habitat, and food is plentiful because of drift organisms. In addition, the accumulation of debris in pools provides an ideal substrate for benthic macroinvertebrates which are more accessible to fishes. These points are seemingly emphasized in this study as 90% of the total fishes caught, 1757 of 1979, were taken from the pools.

Although only 222 fishes, 10% of those captured, were taken from the riffles, the population was greater than that for the pools on an areal basis, 3896 and 1108/ha in the riffles of Stations I and II, respectively, versus 242 and 185/ha in the pools of Stations I and II, respectively. This is understandable in that riffles are more productive of aufwuchs and benthic fauna than pools because of optimal conditions of light and oxygen, thus providing a better food supply for those fishes which are adapted to cope with the current. The dominant riffle fishes were *Etheostoma caeruleum* and *Percina caprodes*, forms which are uniquely adapted to swift waters by streamlined bodies, enlarged pectoral fins, and degenerate gas bladders (Reid, 1961). Of 14 species taken in the riffles, 7 were of the family Percidae. That fewer fish species are adapted to the riffle community is supported by the acquisition of only 15 species from the riffles, but 42 species from the pool communities.

Longitudinal zonation of the fishes was characterized by a decrease in number/ha and species (39 vs 35) present from Station I to Station II (Table 5). Thompson and Hunt (1930) found that the number of individuals decreased downstream, but the size of the fish increased, so that biomass density remained about the same. There is normally an increase in number of species, correlated with an increasingly more diverse habitat, as one moves downstream (Burton and Odum, 1945; Kendeigh, 1961; Larimore and Smith, 1963). That such was not the case in this study is due in part to the absence of a discreet riffle at Station II. Only 3 of 10 species were darters at this station, as opposed to 7 of 9 species being darters at the riffle of Station I.

Two specimens of *Noturus eleutherus* were taken at Station II. These constitute an extension of the known range for this species (Robison, 1969). The specimens are now located in the University of Minnesota Museum of Natural History.

A Pre-impoundment Limnological Study of the Strawberry River in Northeastern Arkansas

The authors thank the Arkansas Game and Fish Commission, particularly Richard Broach and Robert Baker, for assistance in collecting the fish data. Samuel Eddy

verified identifications of the fishes and George A. Moore identified several of the minnows and darters. Max A. Nickerson critically read the manuscript.

TABLE 1. Physicochemical Characteristics, Station I, 30 September 1967-8 June 1968.

	9-30-67		1-20-68		6-8-68	
	Pool	Riffle	Pool	Riffle	Pool	Riffle
Oxygen, ppm	7.8	7.6	10.0	9.9	6.5	6.9
Percent Oxygen Saturation	74.0	73.0	83.0	82.0	77.0	83.0
Carbon dioxide, ppm	2.3	3.0	5.0	3.5	3.3	3.2
Alkalinity, ppm	150.8	160.0	68.0	70.0	249.0	231.0
pH	7.7	7.7	7.7	7.1	7.6	7.6
Air Temperature, °C	14.4	14.4	8.5	8.4	30.5	30.5
Water Temperature, °C	13.7	13.7	7.2	7.4	25.0	25.0
Turbidity, ppm	less than 25.0	—	41.0	—	less than 25.0	—
Light penetration, cm	71.0*	—	25.0	—	36.0*	—

*Indicates a reading on the bottom

TABLE 2. Physicochemical Characteristics, Station II, 30 September 1967 - 8 June 1968. No samples taken on 1-20-68 at riffle because of flooded conditions.

	9-30-67		1-20-68	6-8-68	
	Pool	Riffle	Pool	Pool	Riffle
Oxygen, ppm	8.9	8.8	9.7	7.1	7.3
Percent Oxygen Saturation	86.0	85.0	82.0	88.0	91.0
Carbon Dioxide, ppm	3.0	3.0	5.5	0.6	1.0
Alkalinity, ppm	188.0	185.0	110.0	256.0	254.0
pH	7.8	7.8	7.4	8.0	7.9
Air Temperature, °C	16.6	16.6	11.0	27.5	27.5
Water Temperature, °C	14.1	14.1	8.1	25.5	25.0
Turbidity, ppm	less than 25.0	—	94.0	less than 25.0	—
Light penetration, cm	58.0	—	13.0	98.0	—

Henry W. Robison and George L. Harp

TABLE 3. Mean Number of Benthic Macrofauna expressed as No./M², Station I and II Pools, 30 September 1967, 8 June 1968.

	Station I			Station II		
	9-30-67	1-20-68	6-8-68	9-30-67	1-20-67	6-8-68
Oligochaeta	0	43.0	28.7	401.7	143.3	43.0
Hirudinea	0	0	0	14.3	0	7
Acarina	0	14.3	0	0	0	0
Insecta						
Ephemeroptera						
Caenis	0	0	0	14.3	14.3	14.3
Brachycercus	0	0	14.3	0	0	0
Isonychia	0	0	100.3	43.0	0	71.7
Stenonema	0	0	6.7	43.0	0	14.3
Potamanthus	0	0	0	28.7	0	0
Odonata						
Aeschnida	28.7	0	0	0	0	0
Macromia	0	0	0	0	0	14.3
Coleoptera						
Elmidae						
(larvae)	28.7	0	0	71.7	14.3	0
Diptera						
Chironomidae						
(larve)	0	43.0	1032.7	71.7	57.3	1305.7
(pupae)	71.7	0	57.3	71.7	0	200.7
Simulium	0	0	0	14.3	0	14.3
Quantitative Totals	387	301	3937	2324	688	5036
Qualitative Totals	3	3	6	10	4	8

A Pre-impoundment Limnological Study of the Strawberry River in Northeastern Arkansas

TABLE 4. Mean Number of Benthic Macrofauna expressed as No./M², Station I and II Riffles, 30 September 1967 and 8 June 1968. No samples taken on 20 January 1968 at Station II because of flooded conditions.

	Station I			Station II	
	9-30-67	1-20-68	6-8-68	9-30-67	6-8-68
Oligochaeta	39.7	7.3	7.3	57.3	3.7
Turbellaria	93.3	0	3.7	0	0
Gastropoda					
Pleuroceridae	3.7	3.7	0	0	0
Insecta					
Ephemeroptera					
Ephoron	0	0	3.7	0	0
Caenis	32.3	0	0	36.0	18.0
Pseudocloeon	0	0	3.7	0	0
Isonychia	208.0	14.6	82.3	60.7	86.0
Stenonema	172.0	7.3	36.0	219.0	75.3
Potamanthus	0	0	0	61.0	3.7
Plecoptera					
Neoperla clymene	0	0	29.0	0	0
Megaloptera					
Corydalus cornutus	61.0	0	3.7	3.7	0
Trichoptera					
(Unidentified Pupae)	28.7	0	7.3	0	0
Cheumatopsyche	760.3	10.7	276.3	10.6	3.7
Chimarra	850.3	0	18.0	14.3	11.0
Coleoptera					
Elmidae (adult)	32.3	0	3.7	0	3.7
(larvae)	82.7	7.3	3.7	25.3	0
Psephenus herricki	0.3	0	11.0	0	0
Diptera					
Chironomidae (larvae)	54.0	14.3	258.3	125.7	333.3
(pupae)	7.3	0	0	25.3	75.3
Simulium	764.0	0	211.7	0	0
Tabanidae	7.3	0	0	0	0
Lepidoptera					
Elophila	3.7	0	0	0	0
Quantitative Totals	8080	193	2873	1915	1840
Qualitative Totals	18	7	16	11	10

TABLE 5. Fishes collected at Stations I and II, 7-11 August 1967.

Taxa	Station I		Station II	
	Pool	Riffle	Pool	Riffle
Lepisosteidae				
Lepisosteus osseus	10	0	3	0
Clupeidae				
Dorosoma cepedianum	247	0	456	0
Hiodontidae				
Hiodon tergisus	0	0	20	0
Catostomidae				
Carpionodes cyprinus	10	0	19	2
Hypentelium nigricans	12	0	5	0
Ictiobus bubalus	0	0	4	0
I. cyprinellus	3	0	5	0
I. niger	1	0	5	0
Moxostoma erythrurum	15	0	116	3
Cyprinidae				
Campostoma anomalum	32	0	0	0
Cyprinus carpio	20	0	19	0
Hybopsis amblops	0	0	65	8
Notemigonus crysoleucas	3	0	0	0
Notropis whipplei	0	0	2	1
N. chrysocephalus	15	0	0	0
N. boops	3	0	1	0
N. texanus	0	0	1	0
N. venustus	1	0	3	0
Pimephales notatus	3	0	0	0
P. tenellus	32	0	13	7
Semotilus atromaculatus	14	0	0	0
Ictaluridae				
Ictalurus natalis	2	0	0	0
I. punctatus	9	0	17	0
Noturus eleuthurus	0	0	2	2
N. exilis	12	0	0	0
N. miurus	8	0	19	0
Pygodictis olivaris	11	0	2	0

A Pre-impoundment Limnological Study of the Strawberry River in Northeastern Arkansas

TABLE 5 (continued)

Taxa	Station I		Station II	
	Pool	Riffle	Pool	Riffle
Cyprinodontidae				
<i>Fundulus olivaceus</i>	18	0	23	0
Atherinidae				
<i>Labidesthes sicculus</i>	3	0	0	0
Centrarchidae				
<i>Ambloplites rupestris</i>	5	0	0	0
<i>Lepomis cyanellus</i>	42	0	0	0
<i>L. gibbosus</i>	0	0	7	0
<i>L. macrochirus</i>	45	2	10	0
<i>L. megalotis</i>	110	0	85	8
<i>Micropterus dolomieu</i>	0	0	1	0
<i>M. punctulatus</i>	40	0	18	0
<i>M. salmoides</i>	16	0	2	0
<i>Promoxis annularis</i>	0	0	2	0
<i>P. nigromaculatus</i>	7	0	2	0
Percidae				
<i>Etheostoma blenniodes</i>	0	9	0	0
<i>E. caeruleum</i>	0	72	0	12
<i>E. euzonum</i>	0	1	0	0
<i>E. flabellare</i>	0	6	0	2
<i>E. whipplei</i>	0	15	0	0
<i>E. zonale</i>	0	5	0	0
<i>Percina caprodes</i>	12	34	3	25
<i>Stizostedion vitreum</i>	0	0	1	0
Sciaenidae				
<i>Aplodinotus grunniens</i>	24	0	41	0
Cottidae				
<i>Cottus carolinae</i>	0	7	0	3
Quantitative Totals	785	151	972	71
Qualitative Totals	32	9	32	10

LITERATURE CITED

- AGGUS, L. R. and L. O. WARREN. 1965. Bottom organisms of the Beaver Reservoir Basin: a pre-impoundment study. *J. Kansas Entomol. Soc.*, 38(2): 163-178.
- AMERICAN PUBLIC HEALTH ASSOCIATION. 1960. Standard methods for the examination of water and waste water. APHA, 11th Ed., 626 p.
- ARMITAGE, K. B. 1961. Distribution of riffle insects of the Firehole River, Wyoming. *Hydrobiologia*, 17(1/2): 152-174.
- BAILEY, R. M., E. A. LACHNER, C. C. LINDSEY, C. R. ROBINS, P. M. ROEDEL, W. B. SCOTT, and L. P. WOODS. 1960. A list of the common and scientific names of fishes from the United States and Canada. *Amer. Fish. Soc., Spec. Publ. 2*, 102 p.
- BURTON, G. W. and E. P. ODUM. 1945. The distribution of stream fish in the vicinity of Mountain Lake, Virginia. *Ecology*, 26(2): 182-194.
- CAMPBELL, R. S. and J. L. FUNK. 1953. The Black River basin in Missouri. *Univ. Missouri Studies*, 26(2): 11-21.
- CRONEIS, C. 1930. Geology of the Arkansas Paleozoic Area. *Arkansas Geol. Surv., Bull. 3*, 457 p.
- EDDY, S. 1957. How to know the freshwater fishes. Wm. C. Brown Co., Dubuque, Iowa. 253 p.
- GERSBACHER, W. M. 1937. Development of stream bottom communities in Illinois. *Ecology*, 18(3): 359-390.
- HANEBRINK, E. L. 1965. Summer net plankton in Sardis Reservoir, Mississippi. *Southwest. Nat.*, 10(4): 261-277.
- HICKMON, A. J. 1941. Climate of Arkansas. p. 773-782. In *Climate and Man. Yearbook of Agriculture*, U. S. Dept. Agri.
- HUBBS, C. L. and K. F. LAGLER. 1958. Fishes of the Great Lakes Region. *Bull. Cranbrook Inst. Sci.*, 26: 1-213.
- KENDEIGH, S. C. 1961. *Animal Ecology*. Prentice-Hall, Inc., Englewood Cliffs, N. J. 468 p.
- LARIMORE, R. W. and P. W. SMITH. 1963. The fishes of Champaign County, Illinois as affected by 60 years of stream changes. *Bull. Illinois Nat. Hist. Surv.* 382 p.
- MATHIS, B. J. 1965. Community structure of benthic macroinvertebrates in an intermittent stream receiving oil field brines. Ph.D. Thesis, Oklahoma State Univ. 52 p.
- MINSHALL, G. W. and J. N. MINSHALL. 1966. Notes on the life history and ecology of *Isoperla clio* (Newman) and *Isogenus decicus* Walker (Plecoptera: Perlodidae). *Amer. Midl. Natur.*, 76(2): 340-350.
- MOFFETT, J. W. 1936. A quantitative study of the bottom fauna in some Utah streams variously affected by erosion. *Bull. Univ. Utah*, 26: 1-32.
- MOORE, G. A. 1957. Fishes. p. 31-210. In W. F. Blair, A. P. Blair, P. Brodkorb, F. R. Cagle, and G. A. Moore (ed.) *Vertebrates of the United States*. McGraw-Hill, New York.
- and J. M. PADEN. 1950. The fishes of the Illinois River in Oklahoma and Arkansas. *Amer. Midl. Natur.*, 44(1): 76-95.
- NEEDHAM, P. R. 1938. Trout streams. Ithaca, New York. 233 p.
- NEEL, J. K. 1951. Interrelations of certain physical and chemical features in a headwater limestone stream. *Ecology*, 32(3): 368-391.
- O'CONNELL, T. R. and R. S. CAMPBEILL. 1953. The benthos of Black River and Clearwater Lake, Missouri. *Univ. Missouri Studies*, 26(2): 23-41.
- PENNAK, R. W. 1953. Freshwater invertebrates of the United States. The Ronald Press Co., New York 769 p.
- PFLIEGER, W. L. 1966. A check-list of the fishes of Missouri. with keys for identification. Missouri Dept. Cons. Div. Fish., D-J Ser. No. 3, 63 p.
- REID, G. K. 1961. *Ecology of inland waters and estuaries*. Reinhold Publishing Corp., New York. 357 p.
- ROBISON, H. W. 1968. A pre-impoundment investigation of the Strawberry River. M. S. Thesis, Arkansas State Univ., State University, 40 pp.
- . 1969. An extension of the known range for *Noturus eleutherus* Jordan (Ictaluridae). *Southwest. Nat.*, 14(2): 256-257.
- SOIL CONSERVATION SERVICE, U. S. DEPT. OF AGRICULTURE. 1964. Work plan for watershed protection and flood prevention, Cooper Creek Watershed, Lawrence County, Arkansas. 51 p.
- STEHR, W. C. and J. W. BRANSON. 1938. An ecological study of an intermittent stream. *Ecology*, 19(2): 294-310.
- SUBLETTE, J. E. 1949. Ecological studies of the Clear Creek Rapids. M. S. Thesis, Univ. Arkansas. 16 p.

- SULLIVAN, K. C. 1929. Notes on the aquatic life of the Niangua River, Missouri, with special references to insects. *Ecology*, 10: 322-325.
- THOMPSON, D. H. and F. D. HUNT. 1930. The fishes of Champaign County: a study of the distribution and abundance of fishes in small streams. *Illinois Nat. Hist. Surv. Bull.*, 19(1): 1-101.

- USINGER, R. L. 1963. Aquatic insects of California. Univ. California Press, Berkeley and Los Angeles. 508 p.
- VAN KIRK, R. R. 1962. Some ecological and physical aspects of a cool water stream in northwestern Arkansas, with special reference to trout production. M. S. Thesis, Univ. Arkansas. 56 p.
- WELCH, P. S. 1948. Limnological methods. McGraw-Hill, New York. 370 p.

Ichthyofaunal Diversification and Distribution In The Big Creek Watershed, Craighead and Greene Counties, Arkansas

James T. Jenkins¹ and George L. Harp
Division of Biology, Arkansas State University
State University, Arkansas 72467

ABSTRACT

Big Creek is a relatively small deltaic stream, in northeastern Arkansas, in an area of intense cultivation. Recently it has been dredged in the interest of flood control. Lost Creek and Mud Creek are the major tributaries of Big Creek and collectively drain the Big Creek watershed. The streams were found to have relatively low alkalinity, moderate carbon dioxide, adequate oxygen values, and relatively high turbidity. Channeling of Big Creek and Lost Creek has effectively destroyed distinct pool-riffle biocies and reduced the number of acceptable spawning areas. Lost Creek, also, receives effluent from residential dwellings, a secondary treatment sewage plant, and a meat rendering plant. Mud Creek, in the absence of channeling and deleterious effects of effluents, provided a relatively greater diversity of habitat than did Big Creek or Lost Creek.

A total of 21 species were collected in the streams. Big Creek supported 17 species while Mud Creek and Lost Creek supported 14 and 11 species, respectively. Five of the 11 species collected in Lost Creek are characteristic of streams with plentiful organic debris and were not collected, in numbers, at any other station in the watershed.

Of the 2,209 fishes collected, *Notropis umbratilis*, *Fundulus olivaceus*, and *Leomis cyanellus* made up 63% of the total and were procured from all stations. Their relative abundance is supported by their ability to withstand high turbidity and limited competition due to depth effect.

Limited species included *Ictalurus natalis*, *Aphredoderus sayanus*, and *Etheostoma gracile* in Mud Creek; *Dorsoma cepedianum* in Lost Creek; and the headwater species, *Semotilus atromaculatus*, in Big Creek and Mud Creek. *Cyprinus carpio*, *Ictalurus melas*, *Gambusia affinis*, and *Notemigonus crysoleucas* were also limited, in relative numbers, to Lost Creek.

INTRODUCTION

Big Creek is a relatively small deltaic stream, in northeastern Arkansas, in an area of intense cultivation. Recently it has been dredged in the interest of flood control for surrounding farm land. Lost Creek and Mud Creek are the major tributaries of Big Creek and collectively drain the Big Creek watershed.

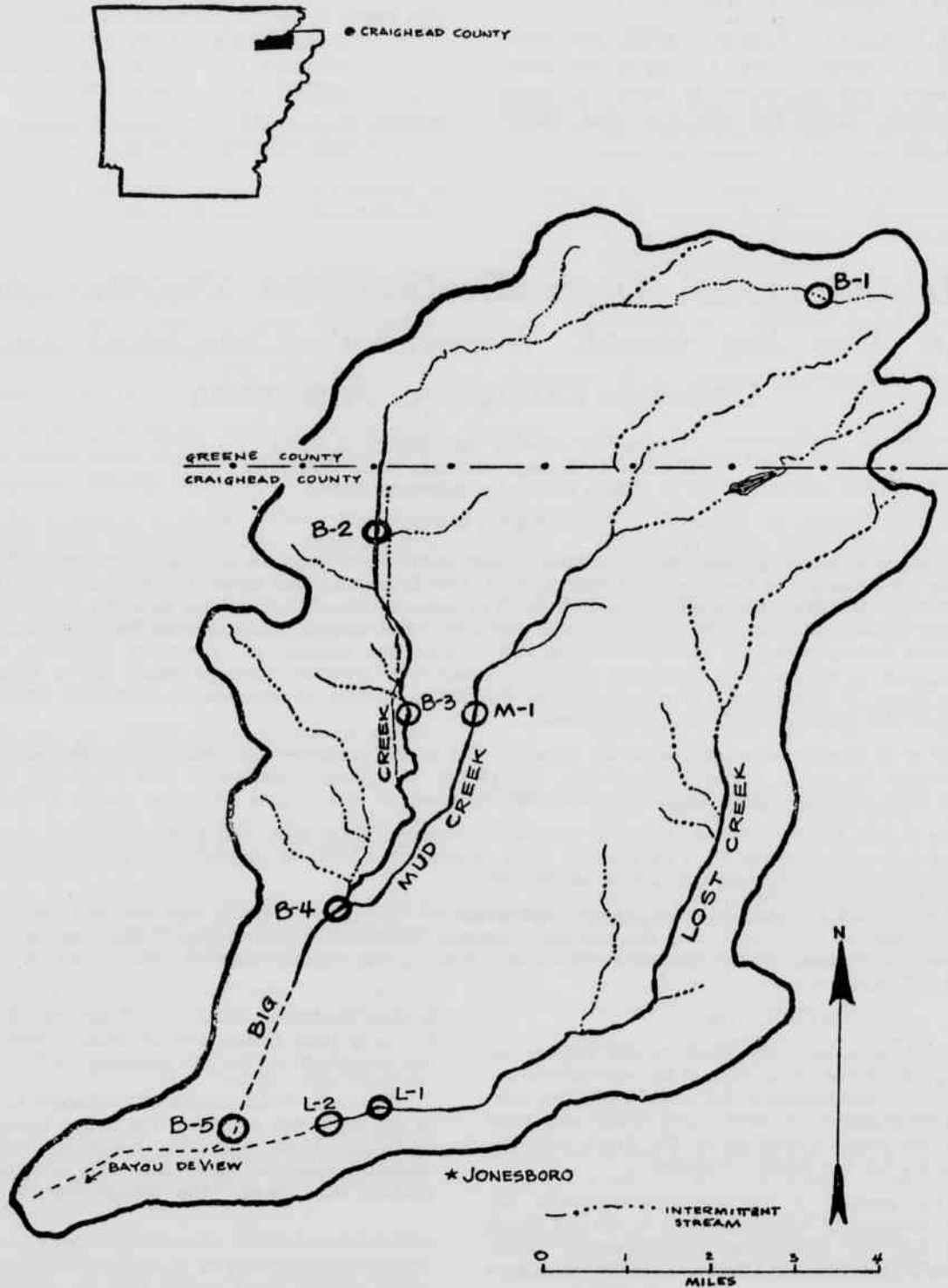
It is the purpose of this study to determine the qualitative variation of fish populations in the Big Creek watershed and the co-existing physicochemical conditions. Further, the effect of effluents from the Jonesboro

Sewage Treatment Plant and Broadway Meat Packing Company (Lost Creek) and intensive cultivation (the entire watershed) on the fish population will be observed.

The major soils immediately adjacent to the streams of the Big Creek watershed are of the Falaya-Collins association. These are deep, poorly to moderately well drained, moderately permeable, silty bottomed and soils washed from loess. The poorly drained Falaya soils

¹Present address: Rt. 3, Quitman, Ga. 31643.

FIGURE I. BIG CREEK WATERSHED



Ichthyofaunal Diversification and Distribution in the Big Creek Watershed, Craighead and Greene Counties, Arkansas

have grayish-brown silt loam surface soil over gray and in the lower part of the subsoil. This association is brown or yellowish-brown silt loam that is mottled gray used mainly for cotton, soybeans, small grains, and pastures in Craighead County (Soil Conservation Service, 1962).

Big Creek arises four miles SE of Walcott, Greene County, Arkansas. It flows 23 miles through Craighead County, Arkansas, in a valley of Crowley's Ridge and becomes Bayou DeView Ditch five miles E of Cash, Craighead County, Arkansas. Elevation drops from 460-270 feet during its course, with a mean gradient of 8.3 ft/mi.

The channel averaged 21 feet in width; had high, steep banks; a substrate of mud, sand + gravel; or hard packed clay; and, in several areas, was littered with debris. Water depth ranged from 6 inches in the riffles to 5 feet in the pools. The stream banks were alternately lined by cultivated fields and mixed forests, the latter consisting primarily of oaks, willows, birch, and sweetgum. A few specimens of *Typha latifolia* were present at one station (B-3). No other rooted aquatic vegetation was noted.

Mud and Lost Creek watersheds physically typify the larger Big Creek watershed. Mud Creek arises 2.5 miles south of the origin of Big Creek, flows 7.5 miles to its confluence with Big Creek 3 miles north of Jonesboro, Craighead County, Arkansas, and has a mean gradient of 8 ft/mi.

Lost Creek arises 4.5 miles south of the origin of Big Creek, flows 10 miles SW to its confluence with Big Creek 2 miles WSW of Jonesboro, and has a mean gradient of 9 ft/mi.

MATERIALS AND METHODS

To provide the necessary data, eight stations were established. Five stations were selected on Big Creek, two on Lost Creek, and one on Mud Creek. Each station was spaced appropriately for adequate coverage of the watershed (Figure 1). Exact locations are as follows:

Big Creek

- B-1 SE $\frac{1}{4}$, SW $\frac{1}{4}$, Sec. 23, T 16N, R 4 E, Greene County, Arkansas. Elevation 460 feet.
- B-2 SE $\frac{1}{4}$, SW $\frac{1}{4}$, Sec. 1, T 15 N, R 3 E, Craighead County, Arkansas. Elevation 340 feet.
- B-3 SE $\frac{1}{4}$, SW $\frac{1}{4}$, Sec. 13, T 15 N, R 3 E, Craighead County, Arkansas. Elevation 320 feet.
- B-4 SE $\frac{1}{4}$, NW $\frac{1}{4}$, Sec. 35, T 15 N, R 3 E, Craighead County, Arkansas. Elevation 300 feet.
- B-5 NE $\frac{1}{4}$, SE $\frac{1}{4}$, Sec. 16, T 14 N, R 3 E, Craighead County, Arkansas. Elevation 270 feet.

Lost Creek

- L-1 SW $\frac{1}{4}$, SW $\frac{1}{4}$, Sec. 7, T 14 N, R 4 E, Craighead County, Arkansas. Elevation 300 feet.
- L-2 NW $\frac{1}{4}$, NW $\frac{1}{4}$, Sec. 13, T 14 N, R 3 E, Craighead County, Arkansas. Elevation 290 feet.

Mud Creek

- M-1 SW $\frac{1}{4}$, SW $\frac{1}{4}$, Sec. 18, T 15 N, R 4 E, Craighead County, Arkansas. Elevation 320 feet.

Station B-4 corresponds with Case's (1970) Station 1, stations L-1 and L-2 correspond with those of Jackson (1966) and station B-5 is at one point of Abernathy and Osoinach's (1969) sampling.

Each station was sampled four times between 22 February 1970 and 10 June 1970.

On each sampling date, the following determinations were conducted at each station: dissolved oxygen determination by the sodium azide modification of the Winkler method (AHPA, 1960), alkalinity and carbon dioxide content by standard limnological procedures (Welch, 1948), hydrogen ion concentration by Beckman pH meter, turbidity by the Jackson turbidimeter, air and water temperature by a thermistor thermometer or a centigrade thermometer, light penetration by Secchi disc, and current by timing a floating disk over a known distance.

Fish samples were procured using a 30 ft x 6 ft seine with 3/16 inch mesh. The collected specimens were preserved temporarily in 10% formalin. After several days they were washed in water, subsequently identified, and preserved in 40% isopropyl alcohol. Riffle and pool areas were sampled.

PHYSICOCHEMICAL CHARACTERISTICS

Streams of the Big Creek watershed were found to have relatively low alkalinity, moderate carbon dioxide, and adequate oxygen values (Table 1).

Alkalinity values increased from February through June at most stations. The lowest value, 13.0 ppm, was recorded on 7 March 1970 and highest value, 100.0 ppm, on 1 June 1970.

Dissolved carbon dioxide fluctuated from 0.0 - 26.5 ppm. Of the eight stations sampled, only B-5 showed relatively uniform values throughout the four sampling dates.

Dissolved oxygen varied only slightly from station to station. Mean values varied from 7.7 - 11.8 ppm. There was a general decrease in dissolved oxygen content from February to June.

The pH values were normally alkaline to slightly acid. The range for all stations was 6.1 - 9.7, with a mean value of 7.4.

Light penetration and turbidity fluctuated greatly depending on water velocity; however, in early spring, while the entire stream systems waters were moving, turbidity increased and light penetration decreased from headwaters to lower stations.

Water temperature, in most instances, was directly proportional to air temperature.

James T. Jenkins and George L. Harp

TABLE 1. Range and mean values of selected physicochemical characteristics for four monthly visits, Big Creek watershed, Craighead and Greene counties, Arkansas, March - June, 1970.

Characteristics	STATION							
	B-1	B-2	B-3	B-4	B-5	M-1	L-1	L-2
Alkalinity, ppm	13-25 (17)	22-100 (67)	30-96 (60)	20-65 (53)	17-65 (7)	20-90 (17)	16-48 (5)	19-35 (7)
Carbon Dioxide, ppm	7.5-24 (14)	10-14 (13)	0-10 (7)	12-22 (17)	6-7.7 (9.9)	10-26.5 (9.2)	0-9 (11.8)	5.5-11 (9.8)
Oxygen, ppm	5.1-10.2 (7.7)	8.8-10.4 (9.3)	6.2-13.2 (10.0)	7.5-12.2 (8.8)	7.6-12.2 (7.8)	4.6-12.8 (7.3)	7.7-17 (7.8)	8.8-11.1 (7.2)
pH	6.1-7.0 (6.6)	6.9-7.4 (7.2)	7.4-9.7 (8.2)	6.9-7.1 (7.0)	7.3-8.3 (6.9)	6.7-8.3 (7.6)	7.0-8.7 (131)	6.5-8.5 (202)
Turbidity, ppm	25-400 (125)	25-153 (57)	25-68 (39)	25-157 (88)	25-98 (7)	25-235 (18)	53-335 (7)	53-350 (5)
Light penetration, inches	4-39 (18)	4-44 (28)	6-26 (16)	4-30 (11)	5-13 (0.6)	4-36 (0.3)	4-10 (0.1)	4-10 (0.4)
Current, ft/sec	0-0.3 (0.1)	0-2.1 (0.5)	0-0.4 (0.2)	0-1.0 (0.3)	0.1-13 (9.9)	0.1-0.8 (9.2)	0-0.1 (11.8)	0-1.0 (9.8)

Stream flow was normally moderate, ranging from negligible to 2.1 ft/sec with a mean value of 0.4 ft/sec.

ICHTHYOFAUNA

A total of 2,209 fishes comprising 21 species were recorded from the collection. Predominant forms included *Notropis umbratilis* (Girard), *Fundulus olivaceus* (Storer), and *Lepomis cyanellus* (Rafinesque).

Species diversity and relative numbers of fishes increased progressively from Station B-1 to Station B-5. Station M-1 was second only to Station B-5 in number of species and total number of specimens collected. In direct contrast to Big Creek, Lost Creek decreased in quality and quantity of fishes from Station L-1 to Station L-2. Station L-2 had lowest number of species and total specimens procured of any station in the watershed (Table 2).

Although several species, such as *N. umbratilis*, *F. olivaceus*, and *L. cyanellus* were collected on most occasions at all stations, other species were limited in their distribution. *Ictalurus natalis* (LeSueur), *Aphredoderus sayanus* (Gilliams), and *Etheostoma gracile* (Girard) were limited to Station M-1. *Dorsoma cepedianum* (LeSueur) was collected at Station L-1 only and on only one occasion. Two species, *Gambusia affinis* (Baird and Girard) and *Semotilus atromaculatus* (Mitchill) were limited to headwaters or areas which presented a highly variable habitat. *Notropis venustus* (Girard) and *Pimphales vigilax* (Baird and Girard) were limited to down stream stations B-4 and B-5; however, on one occasion three

specimens of *N. venustus* were collected at Station M-1. *Notemigonus crysoleucas* (Mitchill) and *Cyprinus carpio* (Linnaeus) were limited, primarily, to stations B-5, L-1 and L-2 with the former being collected also at stations M-1 and B-3. *Micropterus salmoides* (Lacepede) was collected only at stations B-3 and B-5, and *Ictalurus punctatus* (Rafinesque) was limited to stations B-2, B-4 and B-5.

Of the remaining species, *Erimyzon oblongus* (Mitchill), *Notropis chrysocephalus* (Rafinesque), *Ictalurus melas* (Rafinesque), *Lepomis macrochirus* (Rafinesque), *Lepomis megalotis* (Rafinesque), and *Pomoxis annularis* (Rafinesque) all showed a preference to Big Creek with the exception of *I. melas* which was collected in greater numbers in Lost Creek.

DISCUSSION

Big Creek Watershed. Seventeen species of fishes were collected from Big Creek (Table 2). Investigations of five similar streams in Missouri, Kansas, and Oklahoma have reported species diversity to range from 17-50, mean 31 (Hanson and Campbell, 1963; Wade and Craven, 1965; Harrel et al., 1967; Cross and Braasch, 1969).

That Big Creek supported a relatively limited diversity of fish species may be attributed to several factors. Among the most important are relatively low alkalinity, siltation from land cultivation, and periodic dredging of the channel proper.

Ichthyofaunal Diverisification and Distribution in the Big Creek Watershed, Craighead and Greene Counties, Arkansas

TABLE 2. Number and species of fishes collected and frequency of collection in four visits, Big Creek Watershed, Craighead and Greene counties, Arkansas, March - June, 1970. Figures in parentheses indicate percent of total fish contributed by a species at each station.

TAXA	STATIONS							
	B-1	B-2	B-3	B-4	B-5	L-1	L-2	M-1
<i>Dorosoma cepedianum</i>	0	0	0	0	0	2-1 (0.9)	0	0
<i>Cyprinus carpio</i>	0	0	0	0	1-1 (0.17)	1-1 (0.4)	3-2 (3.5)	0
<i>Notemigonus crysoleucas</i>	0	0	3-2 (1.3)	0	2-2 (0.3)	15-4 (6.7)	5-3 (5.9)	14-2 (3.4)
<i>Notropis chrysocephalus</i>	1-1 (0.8)	6-2 (3.7)	1-1 (0.4)	12-2 (3.1)	1-1 (0.17)	0	0	0
<i>Notropis umbratilis</i>	33-4 (27.8)	45-4 (27.6)	84-4 (35.4)	100-4 (26.0)	20-4 (35.0)	59-3 (27.2)	6-1 (7.0)	160-4 (38.8)
<i>Notropis venustus</i>	0	0	0	146-4 (38.0)	219-4 (37.6)	0	0	3-1 (0.7)
<i>Pimephales vigilax</i>	0	0	0	49-4 (12.7)	9-3 (1.55)	0	0	0
<i>Semotilus atromaculatus</i>	34-4 (28.6)	6-2 (3.7)	0	0	0	0	0	7-2 (1.7)
<i>Erimyzon oblongus</i>	17-3 (14.3)	8-2 (4.9)	2-2 (0.8)	5-2 (1.3)	1-1 (0.2)	1-1 (0.4)	0	11-3 (2.7)
<i>Ictalurus melas</i>	12-3 (10.3)	0	1-1 (0.4)	2-2 (0.5)	3-2 (0.5)	21-4 (9.3)	39-3 (45.8)	3-2 (0.7)
<i>Ictalurus punctatus</i>	0	1-1 (0.6)	0	4-3 (1.0)	16-2 (27.0)	0	0	0
<i>Ictalurus natalis</i>	0	0	0	0	0	0	0	3-2 (0.7)
<i>Fundulus olivaceus</i>	17-3 (14.3)	69-4 (42.3)	77-4 (32.5)	43-4 (11.2)	94-4 (16.2)	50-4 (22.2)	5-2 (5.9)	119-4 (28.8)
<i>Gambusia affinis</i>	1-1 (0.8)	0	0	0	0	5-3 (2.2)	5-3 (5.9)	4-2 (0.97)
<i>Aphredoderus sayanus</i>	0	0	0	0	0	0	0	7-3 (1.7)
<i>Lepomis cyanellus</i>	4-2 (3.4)	14-3 (8.6)	27-3 (11.4)	10-1 (2.6)	11-4 (1.9)	65-4 (28.9)	22-4 (25.9)	51-3 (12.1)
<i>Lepomis macrochirus</i>	0	1-1 (0.6)	15-4 (6.3)	6-4 (1.5)	10-3 (1.7)	5-1 (2.2)	0	19-4 (4.6)
<i>Lepomis megalotis</i>	0	9-3 (5.0)	5-4 (2.1)	6-3 (1.5)	6-2 (1.0)	0	0	4-3 (1.0)
<i>Micropterus salmoides</i>	0	0	4-3 (1.7)	0	3-2 (0.5)	0	0	0

TABLE 2. (continued)

TAXA	STATIONS							
	B2	B-2	B-3	B-4	B-5	L-1	L-2	M-1
<i>Pomoxis annularis</i>	0	4-3 (2.4)	17-2 (7.2)	2-2 (0.5)	2-2 (0.3)	1-1 (0.4)	0	0
<i>Etheostoma gracile</i>	0	0	0	0	0	0	0	10-2 (2.4)
Total Specimens	119	163	237	385	582	225	85	413
Total Taxa	8	10	11	12	15	11	7	14

Alkalinity values were moderately low in Big Creek, indicating its relatively low buffering capacity. In general, the more alkaline waters are more productive (Ruttner, 1966). Of greater significance is the intensive land use characteristic of the Big Creek watershed. Subsequent siltation and shallowing of pools are self-evident and deleterious in their effect (Reid, 1961).

Accentuating the situation is the periodic channeling of Big Creek in the interest of floor control. This practice has effectively destroyed distinct pool-riffle biocies and reduced the number of acceptable spawning areas. This is in part reflected in the relatively low number of fishes collected and of those, many being characteristic of the pond-marsh biocies (Kendeigh, 1961).

Jackson (1966) collected 9 species at Station B-5, Abernathy and Osoinach (1969) collected 12 species, and in the present study, 15 species were collected. Jackson collected *Gambusia affinis*, *Notropis galacturus*, and *Etheostoma gracile* from this station, and Abernathy and Osoinach reported *G. affinis*, *Ictalurus natalis*, and *Semotilus atromaculatus*, none of which were taken in this study. The increase in number of species collected at Station B-5 from 1966-70 is probably due primarily to sampling effort.

Mud Creek provided a relatively greater diversity of habitat than did Big Creek. Despite its short length (7.5 vs. 23 miles for Big Creek), and although only one station was sampled, 14 species of fishes were collected. Amongst these were *Aphredoderus sayanus*, *Ictalurus natalis*, and *Etheostoma gracile*, species taken at no other station. Also, the second highest number of total fishes was taken from this station. Although there was little difference in the physicochemical characteristics, Mud Creek, as opposed to Big Creek, had no stream channeling and was flanked primarily by pastured land.

Lost Creek, in spite of its greater length (10 miles) and collections at two stations, supported only 11 and 7 species of fishes at stations L-1 and L-2, respectively. The smallest number of total fishes taken in this study

was at station L-2. Lost Creek, like Big Creek, is periodically channelled. Probably most important, however, is the fact that Lost Creek receives effluent from residential dwellings, a secondary treatment sewage plant (Station L-2), and a meat rendering plant. Formerly, a meat packing plant also released an untreated effluent at Station L-1.

Jackson (1966) collected 6 species of fishes at Station L-1 and 2 species at L-2. He collected *Semotilus atromaculatus* at Station L-1, but it was not taken at that station in this study.

Since no fish were collected in four attempts below the sewage plant, it is probable that the fish population of Lost Creek is isolated.

Effects of inflow from Lost Creek on the fish population of Big Creek is incompletely known since a temporary holding dam was built on Lost Creek by the Arkansas Highway Department. The waters were used daily to wet the newly constructed roadbed and embankments of the Jonesboro bypass.

ICHTHYOFAUNA. Species of Wide Distribution. *Notropis umbratilis*, *Fundulus olivaceus*, and *Lepomis cyanellus* were the most abundant species collected in the Big Creek watershed, contributing 31%, 21%, and 11% respectively, of the total specimens procured. They are primarily pool species inhabiting small warm - water streams with variable current and relatively high turbidity (Trautman, 1957; Larimore, 1961; Cross and Braasch, 1967). *F. olivaceus* is primarily a topwater species, *N. umbratilis* congregates in mid-water, and *L. cyanellus* forages over all depths; thus competition is limited due to depth effect (Sheldon, 1968). Tolerance of turbidity coupled with limited competition suggests possible reasons for their abundance.

Erimyzon oblongus was collected at every station except L-2. This wide distribution was probably due to migratory habits of this species during spring breeding season. They prefer the sand + gravel bottom pools in

Ichthyofaunal Diversification and Distribution in the Big Creek Watershed, Craighead and Greene Counties, Arkansas

the headwaters of small streams to spawn. After spawning, they migrate to larger streams to overwinter (Cross, 1967).

Only one other species, *Ictalurus melas*, was widely distributed in the watershed; however, they were collected in greater numbers at stations L-1 and L-2. Deacon (1961) considered the black bullhead to be a highly vagile species and able to withstand high turbidity. They apparently are tolerant of organic pollution, also, as demonstrated in this study and that of an Oklahoma stream (Wade and Craven, 1965).

HEADWATER SPECIES. *Semotilus atromaculatus* was collected only at stations B-1 and B-2. This species prefers the headwaters of small, warm-water streams (Trautman, 1957; Hanson and Campbell, 1963; Metcalf, 1966; Branson, 1967; Cross, 1967; Sheldon, 1968), but will migrate to larger pools in late summer.

Gambusia affinis, the mosquito fish, is a particularly hardy fish which is adaptable to most stream environments and feeds on a variety of plankton, as well as some relatively large aquatic insect species (Mulla and Isaak, 1961). Cross (1967) and Trautman (1957) found this species to frequent the headwater pools in intermittent streams, which is evidenced in the collection of specimens from B-1 and M-1.

DOWNSTREAMS SPECIES. The appearance of *Notropis venustus* and *Pimphales vigilax* at stations B-4 and B-5 is perhaps the result of the confluence of Mud Creek and Big Creek at Station B-4. Kuehne (1962), using Horton's (1945) classification of streams, reported that the merging of one stream with another constitutes a progression in stream order. A more varied habitat results in the support of greater numbers of species. Odom et al. (1969) postulated that an increase in species diversity was due to a more complex, thus stable, per capita hierarchy of function in a community. Each rare species is required by a definite number of more common species for its survival and support.

Most centrarchids in this watershed, *Pomoxis annularis*, *Lepomis macrochirus*, and *Micropterus salmoides*, prefer the pond-lake environment (Kendeigh, 1961). It is probable that the present population of these fishes, as well as *Ictalurus punctatus*, are the result of overflowing ponds in the watershed.

Another centrarchid collected downstream, *Lepomis megalotis*, is mostly indigenous to streams, preferring their clear water pools (Trautman, 1957; Metcalf, 1966). This suggests a reason for the fewer specimens of *L. megalotis* collected at times of relatively high turbidity.

Notropis chrysocephalus is a warm-water fish that prefers clear water over sand + gravel-bottom pools in low-gradient streams and migrates to headwaters for breeding (Trautman, 1957). Of the 21 specimens collected, 18 were taken in March. This suggests a temporary migration from below station B-5.

SPECIES OF SPARSE DISTRIBUTION. Station M-1 was unique in that it supported three species of fishes, *Aphredoderus sayanus*, *Etheostoma gracile*, and *Ictalurus natalis*, not found at any other station in the watershed. The characteristics of the pool from which specimens of *A. sayanus* were collected fit perfectly the description given by Trautman (1957). He stated, "The Pirate-perch inhabited pools of streams where the bottom consisted of soft, dark muck which contained much decomposing organic material. Such a bottom usually had many twigs, leaves, roots and duntimber lying upon it." Hellier (1967) reported collecting *A. sayanus* from similar habitats in a Florida stream and discussed their ability to avoid being seined. This ability coupled with habitat preference make them a rarely collected species in the Big Creek watershed.

E. gracile, unlike most darters, occupies lowland pools having muddy bottoms, rather than streams where currents sweep the channel free of silt (Cross, 1967). Wallen (1958) reported this species from several tributaries of the Verdigris River in Oklahoma occupying habitats similar to the Mud Creek station.

The yellow bullhead, *I. natalis*, inhabits quiet, mud-bottom pools in small streams (Metcalf, 1966). Cross (1967) reported this species to avoid interspecific competition and high gradient streams. The nearest competitor, *I. melas*, was collected at station M-1 in a 1:1 ratio with *I. natalis*. This condition could be detrimental to *I. natalis* in future years. Trautman (1957) observed a decrease in numbers of yellow bullhead when the more vagile black bullhead moved into its range.

Dorsoma cepedianum, *Gambusia affinis*, *Cyprinus carpio*, *Notemigonus crysoleucas*, and *Ictalurus melas* were fishes collected in greatest numbers at stations L-1 and L-2. All are indicative of streams with plentiful organic debris (Trautman, 1957; Wade and Crave, 1965; Cross, 1967.)

D. cepedianum was collected on only one occasion and this being at station L-1 when a dense plankton bloom was present. They apparently migrated from a large pool directly behind the packing plant to feed upon the abundant plankton. *D. cepedianum* consumes microorganisms (both plant and animal) that are strained indiscriminately from water as it passes over the gills (Cross, 1967).

Wade and Craven (1965) reported *G. affinis* to have a distinct tolerance of sewage. This was apparent in the present study as one specimen was captured at the periphery of the sewage plant outfall. They also reported *N. crysoleucas* and *C. carpio* to frequent stream habitats of low gradient and plentiful organic waste. Confluence of Lost Creek with Big Creek near station B-5 would possibly account for their presence at this location. *N. crysoleucas* was collected at one other station, B-3, where their presence could perhaps be explained by the abundant food supply. On the two dates *N. crysoleucas*

were procured *Zygnema* spp. was prevalent. Only two other stations, B-2 and L-1, supported a noticeable bloom of algae during the course of this study.

I. melas is highly tolerant of many types of industrial and domestic loplutants in small, warm-water streams (Trautman, 1957). It frequently becomes over-populated in small streams with a consequent dwarfing in size (Cross, 1967).

The physicochemical data do not reflect it, but physical observations such as odor, plankton blooms, *Tubifex* populations along pool shorelines and the species composition of the ichthyofauna of Lost Creek, attest to the profound effect of organic pollutants upon this section of the Big Creek watershed.

ACKNOWLEDGEMENTS.

We express sincerest appreciation to Gary McGrew, Tracy McGraw, Jim Pyland, James Krego, and Tom Ammons for assistance in the field collections; Dave Hawkins for assistance in collection and identification of the vascular aquatic plants and algae; Dr. M. A. Nickerson, Assistant Professor of Zoology, and Dr. J. K. Beadles, Chairman of the Division of Biological Sciences, who critically read the manuscript.

LITERATURE CITED

- ABERNATHY, F. W. and J. K. OSOINACH. 1969. A survey of fishes in Big Creek. Unpublished paper. 13 p.
- AMERICAN PUBLIC HEALTH ASSOCIATION. 1960. Standard methods for the examination of water and waste water. APHA, 11th ed., 626 p.
- BRANSON, B. A. 1967. Fishes of the Neosho River system in Oklahoma. *Am. Midl. Nat.* 78(1):126-154.
- CASE, MARY R. 1970. The benthic macroinvertebrate fauna of an Ozark and a deltaic stream. Unpublished M. S. Thesis. Arkansas State University. 31 p.
- CRONEIS, C. 1930. Geology of the Arkansas paleozoic area. Arkansas Geological Survey, Bull. 3, Little Rock. 457 p.
- CROSS, F. B. 1967. Handbook of fishes of Kansas. University of Kansas, Lawrence. 537 p.
- _____ and M. BRAASCH. 1968. Qualitative changes in the fish-fauna of the upper Neosho River system, 1952-1967. *Trans. Kansas Acad. Sci.* 71(3):350-360.
- DEACON, J. E. 1961. Fish populations, following a drought, in the Neosho and Marais des Cygnes Rivers of Kansas. *Univ. Kansas Publ., Mus. Nat. Hist.* 13(9):359-427.
- FENNEMAN, N. M. 1938. Physiography of the eastern United States. McGraw-Hill Book Co., New York. 714 p.
- HANSON, W. D. and R. S. CAMPBELL. 1963. The effects of pool size and beaver activity on distribution and abundance of warm-water fishes in a north Missouri stream. *Am. Midl. Nat.* 69(1):136-149.
- HARREL, R. C., B. J. DAVIS, and T. C. DORRIS. 1967. Stream order and species diversity of fishes in an intermittent Oklahoma stream. *Amer. Midl. Nat.* 78(2):428-436.
- HELLIER, T. R., JR. 1967. The fishes of the Santa Fe River system. *Bull. Florida State Mus.* 11(1):1-46.
- HORTON, R. E. 1945. Erosional development of streams and their drainage basins; hydrophysical approach to quantitative morphology. *Bull. Geol. Soc. Amer.* 56:275-370.
- JACKSON, R. E. 1966. Spring distribution of fishes in a polluted stream in northeast Arkansas. Unpublished paper. 10 p.
- KENDEIGH, S. C. 1961. Animal ecology. Prentice-Hall, Inc. Englewood Cliffs, N. J. 468 p.
- KUEHNE, R. A. 1962. A classification of streams, illustrated by fish distribution in an eastern Kentucky Creek. *Ecology* 43(4):608-614.
- LARIMORE, R. W. 1961. Fish population and electrofishing success in a warm-water stream. *J. Wildl. Mgmt.* 25(1):1-12.
- METCALF, A. L. 1966. Fishes of the Kansas River system in relation to zoogeography of the Great Plains. *Univ. Kansas Publ., Mus. Nat. Hist.* 17(3):28-189.
- MULLA, M. S. and L. W. ISAAK. 1961. Field studies on the toxicity of insecticides to the mosquito fish, *Gambusia affinis*. *J. Econ. Ent.* 54(6):1237-1242.
- ODUM, H. T., J. E. CANTLON and L. S. KORNICKER. 1960. An organizational hierarchy postulate for the interpretation of species-individual distributions, species entropy, ecosystem evolution, and the meaning of a species-variety index. *Ecology* 41:395-399.
- REID, G. K. 1961. Ecology of inland waters and estuaries. Reinhold Publishing Corp. New York. 357 p.
- RUTTNER, F. 1953. Fundamentals of limnology. Univ. of Toronto Press. 242 p.
- SHELDON, A. L. 1968. Species diversity and longitu-

nal succession in stream fishes. *Ecology* 49-(2):193-198.

SOIL CONSERVATION SERVICE, U. S. DEPARTMENT OF AGRICULTURE. 1962. General soil map Craighead County, Arkansas, Little Rock.

TRAUTMAN, M. B. 1957. The fishes of Ohio. The Ohio State University Press. Waverly Press, Inc. Baltimore. 683 p.

WADE, F. W. and R. E. CRAVEN. 1965. Changes in fish fauna of Stillwater Creek, Payne and Noble Counties, Oklahoma from 1938 to 1965. *Proc. Okla. Acad. Sci.* 1965:60-66.

WALLEN, G. H. 1958. Fishes of the Verdigris River in Oklahoma. Oklahoma State Univ., Dept. Zool., 57 p.

WELCH, PAUL S. 1948. *Limnological methods*. McGraw-Hill Book Co. New York. 370 p.

Rapid Electroosmosis Measurements

James O. Wear

Central Research Instrument Program

Veterans Administration Hospital

and

Department of Physiology and Biophysics

University of Arkansas Medical Center

Little Rock, Arkansas 72204

ABSTRACT

A cell has been designed and built that allows for rapid measurement of volume moved in a definite time by electroosmosis. The cell is simple to use and is not very elaborate. Using a water jacket, the cell temperature can be controlled to $\pm 0.1^\circ$ C. Measurements are presented for acetonitrile, dimethylformamide, and nitrobenzene at 25° C for applied voltages of 25, 50, 75, and 100 volts.

I. INTRODUCTION

Interest in electroosmotic measurements and especially a cell for rapid measurements arose from attempts to use this phenomenon in electrical circuits. It was believed that electroosmosis could be used for the opening and closing of a switch in an electrochemical relay.

Electroosmosis is a definite phenomena of a system and therefore would have a high reliability. Since each liquid, colloid, or mixture of liquids have different electroosmotic properties, a variety of times would be available for a relay by just changing the chemical component. The operating temperature would cause some limitations on the choice of systems, but many organic liquids could be used over the standard operating range (-65 to $+165^\circ$ F). However, electroosmosis has a temperature dependence and this would have to be studied for most systems to see what its magnitude is.

Since it would be desirable to look at many systems that have not been studied in great detail, it would be

desirable to have a cell in which rapid measurements could be made. A cell for this purpose has been designed and built. Measurements are presented for acetonitrile, dimethylformamide, and nitrobenzene.

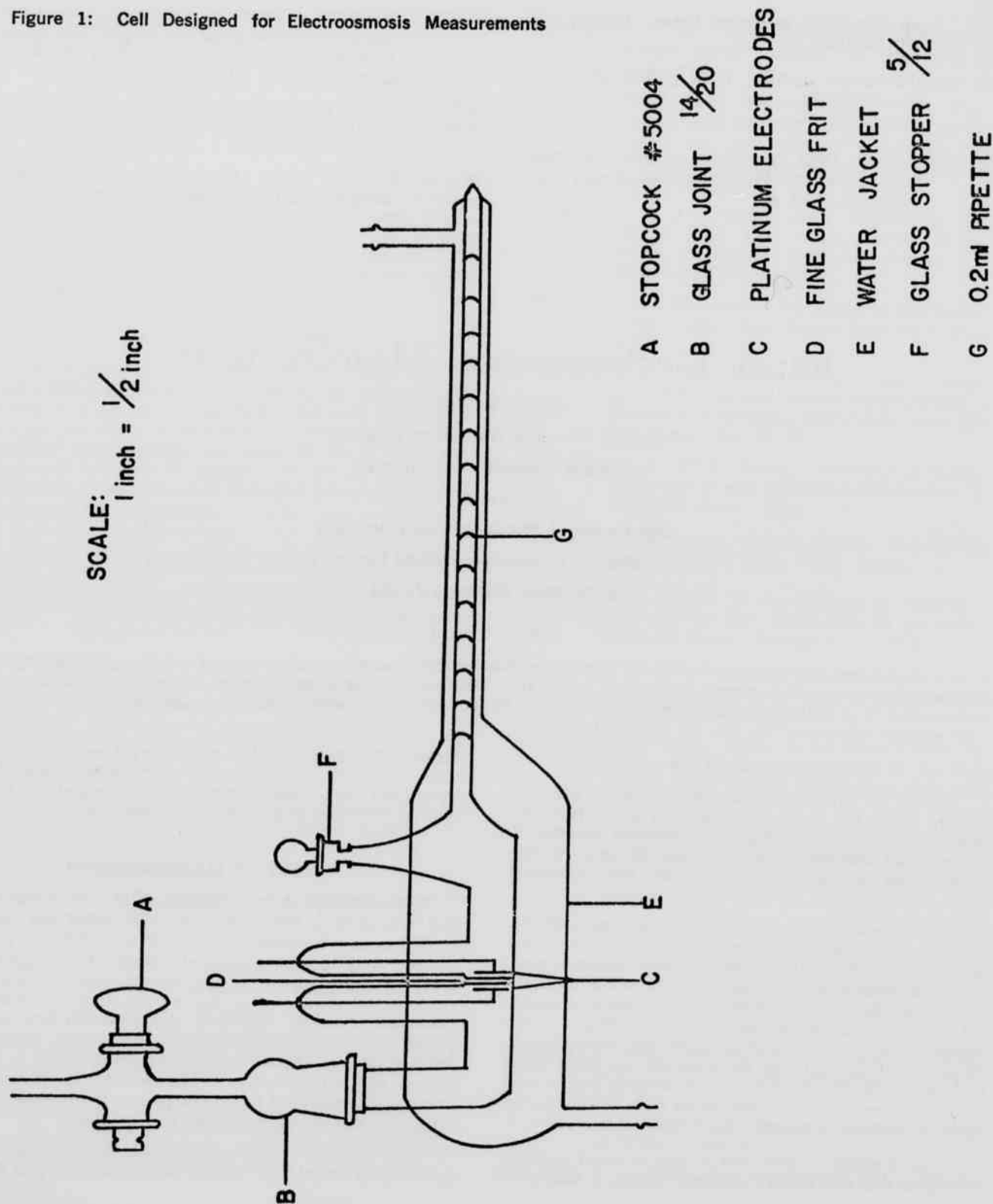
II. THEORY OF ELECTROOSMOSIS

Electroosmosis is the phenomena of a fluid moving with respect to a solid wall when a potential has been applied across the fluid. Ruess first observed this phenomena in 1808 which makes electroosmosis one of the first electrochemical effects to be observed. Extensive experimental studies were carried out later by Wiedemann¹ and Quincke.² Quincke³ in his studies first suggested that a streaming potential should exist between the wall and the fluid. The streaming potential is the reverse of electroosmosis. Electroosmosis is expressed in terms of velocity of flow or in volume moving per unit time. For our purposes volume will be used.

The theory of electroosmosis has been treated extensively by Helmholtz,⁴ Lamb,⁵ Smoluchowski,⁶ and Per-

James O. Wear

Figure 1: Cell Designed for Electroosmosis Measurements



Rapid Electroosmosis Measurements

rin.⁷ All of the treatments arrived at basically the same expression although some considered a single capillary⁴ and other considered a porous plug⁸ separating the electrodes. The derived expression is

$$V = \frac{\epsilon \zeta I}{4\pi \eta \lambda} = \frac{\epsilon \zeta A E}{4\pi \eta l}$$

where V = volume of fluid in cc moved per second

ϵ = dielectric constant of the fluid

I = current

E = applied potential in ESU units

η = viscosity of the fluid in poise

λ = specific resistance of the fluid (includes geometry of the cell)

A = cross-sectional area of the capillary in cm²

l = distance between the electrodes in cm

ζ = "zeta" potential for the electric double layer as a condenser in ESU units

Since A and l are difficult to measure the first form of the equation is generally used. The dielectric constant is near impossible to determine since it would not be for the bulk liquid but just for the double layer which cannot be measured. Since most authors fail to state what they used for ϵ in calculating ζ , lists of these potentials are usually worthless. For this reason it has been suggested⁹ that a new term called the Gouy be defined as:

$$G = \zeta \epsilon / 4\pi \eta$$

This new term would lump all of the characteristics of the fluid into one constant which could be more easily compared.

The temperature dependence of V is extremely complex since the dielectric constant is proportional to e^{-LT}

where T is in degrees Kelvin and L is an empirical parameter; η is proportional to $e^{1/RT}$ where R is the gas constant; and λ is directly proportional to temperature. In addition to these temperature dependences the co-efficients of thermal expansion of both the material of the cell and the considered fluid must be taken into account. It appears that it would be best to measure this temperature dependence of V for any considered system.

III. CELL DESIGN

Since the volume of fluid moved in a unit time is

the important measurement for electrochemical systems using electroosmosis, a cell has been designed for rapidly obtaining these measurements.

Many cells have been designed and used¹⁰⁻¹¹ in the past fifty years. However, most of these cells have been very elaborate pieces of glassware⁹ and use porous plugs¹⁰⁻¹¹⁻¹⁶⁻¹⁸⁻¹⁹ that are difficult to prepare. In addition, most of these cells require a considerable length of time for measurements. Despite the elaborate designs most of these cells were not made in a way to allow easy temperature control. As a result of this design feature, many electroosmotic measurements have been made at room temperature.

In Figure 1 is shown our design for a cell that will allow rapid measurements in a temperature controlled environment. The volume measurements are obtained by measuring the volume moved in the calibrated 0.2 ml pipette (G) as a function of time. The electrodes (C) are bright platinum discs of about one centimeter diameter and placed about 2 millimeters on each side of a fine glass frit plug (D). The starting plug is a medium frit but after heating by the glassblower during the preparation of the cell, the final plug is about a fine frit.

The cell is contained in a glass jacket through which a liquid from a thermostated bath can be pumped. The temperature of the cell can be monitored by a thermocouple. This temperature controlled method can be improved by wrapping the cell jacket with an insulating tape. A range of -20 to +100° C can easily be obtained with this temperature control with a precision of 0.1° C.

A stand to allow for easy leveling and obtainment of a reproducible position was made to hold the cell. This holder was made out of Lucite to prevent a large heat loss to the cell holder, but any nonconducting material could be used.

IV. MEASUREMENTS

The cell has been used for measurements on three liquids that were being considered for relays, acetonitrile, dimethylformamide, and nitrobenzene. All of these liquids were reagent grade and were not further purified.

The measurements were made at 25° C using a bath with a 50-50 volume percent ethylene glycol-water mixture. The liquid was pumped through the cell jacket using a 1/35 hp, 3000 rpm centrifugal pump. The temperature of the jacket was monitored with a copper-constantan thermocouple with a melting ice reference and a K-3 potentiometer.

D.C. voltages of 25, 50, 75, and 100 volts were used for the measurements. These voltages were produced with a Lambda model C-480M regulated power supply.

To cancel out any forces besides those of electroosmosis, measurements were made with the fluid moving in both directions and then these times were averaged. All measurements were made for 0.1 ml volume moved and the time was obtained with a stopwatch.

The results of these measurements for acetonitrile, dimethylformamide, and nitrobenzene are presented in Table I. Each value in Table I is the average of 10 measurements. The results are presented for volume moved as this was the parameter of interest and is a common presentation. The Gouy is also calculated. The value for the streaming potential, 0.0896 volts, agrees well with the literature value of 0.0834 volts.²²

From Table I it can be seen that even with a fluid that moves as slow as nitrobenzene only six minutes are required for a measurement in our cell (0.1 ml volume moved). Of course, this excludes set up time which is about 30 minutes including temperature equilibration time.

TABLE I

Volume of Liquid Moved and $\zeta \epsilon / 4\pi \eta$ from Electroosmosis at Various Voltages for Acetonitrile, Dimethylformamide and Nitrobenzene.

Compound	$\frac{V}{cc/sec/volt}$	Voltage	$\zeta \epsilon / 4\pi \eta$ (Gouy)
Acetonitrile	1.98×10^{-4}	25	1.98×10^{-3}
Acetonitrile	2.17×10^{-4}	50	2.17×10^{-3}
Acetonitrile	2.26×10^{-4}	75	2.26×10^{-3}
Acetonitrile	2.27×10^{-4}	100	2.27×10^{-3}
Dimethylformamide	5.92×10^{-5}	25	5.92×10^{-4}
Dimethylformamide	6.24×10^{-5}	50	6.24×10^{-4}
Dimethylformamide	6.30×10^{-5}	75	6.30×10^{-4}
Dimethylformamide	6.37×10^{-5}	100	6.37×10^{-4}
Nitrobenzene	1.12×10^{-5}	25	1.12×10^{-4}
Nitrobenzene	1.27×10^{-5}	50	1.27×10^{-4}
Nitrobenzene	1.30×10^{-5}	75	1.30×10^{-4}
Nitrobenzene	1.37×10^{-5}	100	1.37×10^{-4}

REFERENCES

- G. Wiedemann, *Pogg. Ann.* **87**, 321 (1852); **99**, 177 (1856).
- G. Quincke, *Pogg. Ann.* **113**, 513 (1861).
- G. Quincke, *Pogg. Ann.* **107**, 1 (1859).
- H. Helmholtz, *Wied. Ann.* **7**, 337 (1879).
- H. Lamb, *Phil. Mag.* **5**, 25, 52 (1888).
- M. von Smoluchowski, discussion in Graetz, "Handbuch der Elektrizität und des Magnetismus" v. II, Barth Leipzig (1914), p. 366.
- J. Perrin, *J. Chem. Phys.* **2**, 601 (1904).
- D. J. O'Connor, *Rec. Tran. Chim.* **75**, 938 (1956).
- S. Gilixelli, *Chemik Polski* **15**, 111 (1917).
- A. F. Gerasimov, *J. Russ. Phys. Chem. Soc.* **58**, 201 (1926).
- S. Gilixelli and J. Wiertelak, *Kolloid Z.* **43**, 85 (1927).
- N. Schonfeldt, *Wiss. Veroffentlich Siemens Konzern.* **7**, 301 (1928).
- P. I. Andrianov, *Kolloid Z.* **61**, 46 (1932).
- F. Fairbrother and A. E. Stubbs, *J. Chem. Soc.* **1935**, 527.
- A. Vasicek, *Chem. Listz* **30**, 173 (1936).
- R. DuBois and A. H. Roberts, *J. Phys. Chem.* **40**, 543 (1936).
- N. A. Krailov, *Colloid J. (U.S.S.R.)* **2**, 119 (1936).
- S. N. Aleshin, *Ibid* **6**, 701 (1940).
- J. D. Porter, *J. Chem. Educ.* **19**, 533 (1942).
- M. Viscontini, *Compt. Rend.* **219**, 92 (1944).
- V. Zajicova and P. Skrivan, *Chem. Listz* **58**, 215 (1964).
- F. Fairbrother and M. Balkin, *J. Chem. Soc.* **389**, (1931).

UNIV. OF ARK. LIBRARY

ARKANSAS ACADEMY OF SCIENCE

Volume XXV

Proceedings

1971

TABLE OF CONTENTS

	Page
Secretary's Report and Financial Statement	2
Historian's Report — A Half Century of the Arkansas Academy of Science	4
Program	6
Collegiate Academy — Minutes, Financial Report and Abstracts of Papers	9
FRANK L. SETLIFF: The Preparation of o-Fluorobenzoic Acid. An Elementary Organic Laboratory Experiment	12
JOE M. GUENTER: Physics and Environmental Studies	13
KENNETH W. COLE: A Consideration of Macro-Climatic and Macro-Biotic Change in the Ozark Highlands during Post-Glacial Times	15
GLORIA YOUNG: Environmental Adaptation: The Otomi Indians of the Mezquital Valley	20
PATRICK E. MARTIN: Historical Archeology in Arkansas	23
JIMMIE D. BARRACK and LEO J. PAULISSEN: The Demonstration, and a Suggested Immune Role, of Mouse Antibodies against <i>Salmonella enteritidis</i> Endotoxins	25
RICHARD L. MEYER: Notes on the Algae of Arkansas. I. <i>Chrysococcus</i> , <i>Kephyrion</i> , <i>Kephyriopsis</i> , <i>Pseudokephyrion</i> and <i>Stenokalyx</i>	31
WILLIAM F. EVANS: A Facility for the Biological Treatment of a Complex Chlorophenolic Waste — A Preliminary Report	38
DANIEL L. MARSH: Studies of <i>Arundinaria</i> : Experimental Induction of Flowering and Additional Observation in the Field	40
MICHAEL I. JOHNSON: A Survey of the Vascular Flora of Poinsett County, Arkansas	42
LELAND F. MORGANS: The Effects of Urethan on Fish Epithelial and Fibroblast Growth <i>in vitro</i>	52
CHARLES L. SELMAN and HARVEY E. BARTON: The Relative Abundance, Seasonal Distribution and Taxonomy of Sphingidae of Northeast Arkansas	56
PEGGY RAE DORRIS: Phosphorescent Animal Forms of Arkansas	69
HENRY W. ROBISON and GEORGE L. HARP: A Pre-Impoundment Limnological Study of the Strawberry River in Northeastern Arkansas	70
JAMES T. JENKINS and GEORGE L. HARP: Ichthyofaunal Diversification and Distribution in the Big Creek Watershed, Craighead and Greene Counties, Arkansas	79
JAMES O. WEAR: Rapid Electroosmosis Measurements	87