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Academy Editors

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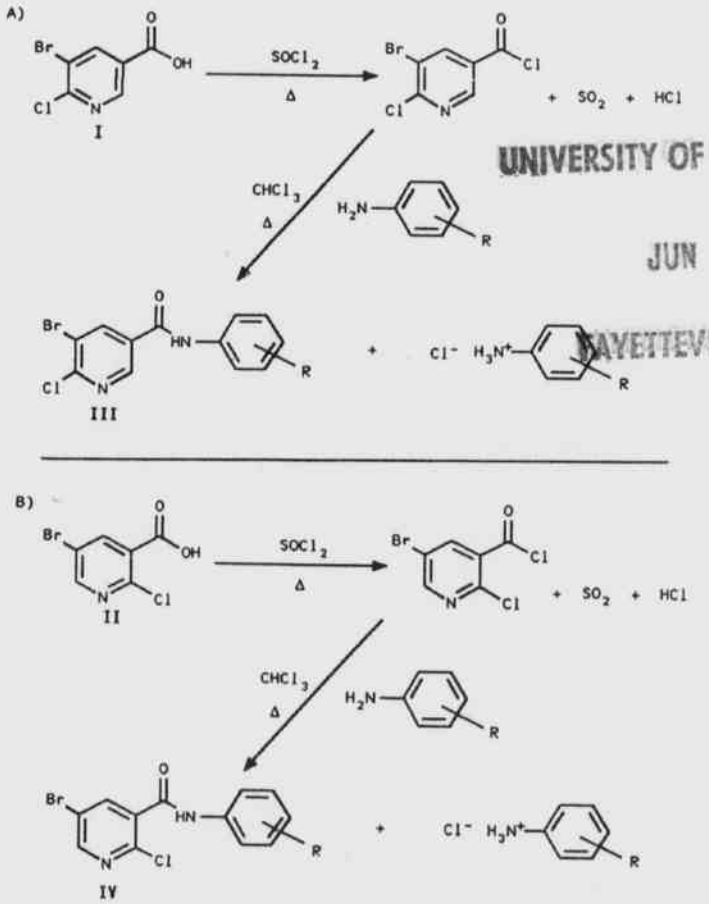


ARKANSAS ACADEMY OF SCIENCE
DEPT. OF NATURAL SCIENCE
MONTICELLO, ARKANSAS 71655

Library Rate

75th ANNIVERSARY

Arkansas Academy of Science, Dept. of Natural Science, University of Arkansas at Monticello
Monticello, Arkansas 71655

PAST PRESIDENTS OF THE ARKANSAS ACADEMY OF SCIENCE

Charles Brookover, 1917
Dwight M. Moore, 1932-33, 64
Flora Haas, 1934
H. H. Hyman, 1935
L. B. Ham, 1936
W. C. Munn, 1937
M. J. McHenry, 1938
T. L. Smith, 1939
P. G. Horton, 1940
I. A. Willis, 1941-42
L. B. Roberts, 1943-44
Jeff Banks, 1945
H. L. Winburn, 1946-47
E. A. Provine, 1948
G. V. Robinette, 1949
John R. Totter, 1950
R. H. Austin, 1951
E. A. Spessard, 1952
Delbert Swartz, 1953
Z. V. Harvalik, 1954
M. Ruth Armstrong, 1955
W. W. Nedrow, 1956
Jack W. Sears, 1957
J. R. Mundie, 1958
C. E. Hoffman, 1959
N. D. Buffaloe, 1960
H. L. Bogan, 1961
Trumann McEver, 1962
Robert Shideler, 1963
L. F. Bailey, 1965
James H. Fribourgh, 1966
Howard Moore, 1967
John J. Chapman, 1968
Arthur Fry, 1969
M. L. Lawson, 1970
R. T. Kirkwood, 1971
George E. Templeton, 1972
E. B. Wittlake, 1973
Clark McCarty, 1974
Edward Dale, 1975
Joe Guenter, 1976
Jewel Moore, 1977
Joe Nix, 1978
P. Max Johnston, 1979
E. Leon Richards, 1980
Henry W. Robison, 1981
John K. Beadles, 1982
Robbin C. Anderson, 1983
Paul Sarrah, 1984
William L. Evans, 1985
Gary Heidt, 1986
Edmond Bacon, 1987
Gary Tucker, 1988
David Chittenden, 1989
Richard K. Speairs, Jr. 1990
Robert Watson, 1991

INSTITUTIONAL MEMBERS

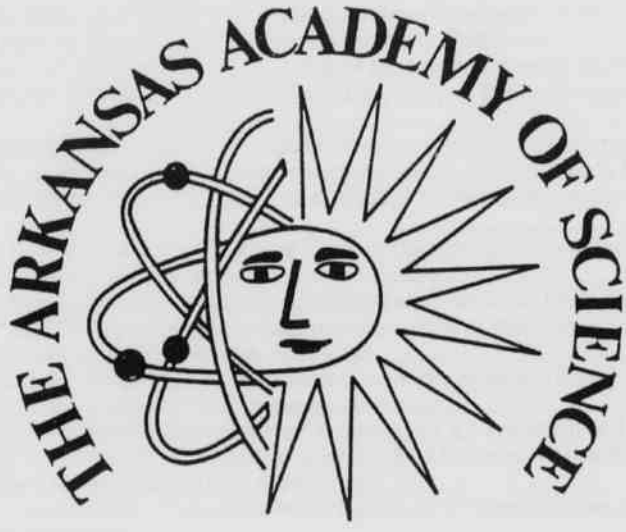
The Arkansas Academy of Science recognizes the support of the following institutions through their Institutional Membership in the Academy.

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

EDITORIAL STAFF

COVER: A) Preparation of the 5-bromo-6-chloronicotinamides and B) the 5-bromo-2-chloronicotinamides. Frank Setliff and Jody Caldwell.

ARKANSAS ACADEMY OF SCIENCE



5, 6 APRIL, 1991

75TH ANNUAL MEETING

UNIVERSITY OF ARKANSAS
FAYETTEVILLE

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PROCEEDINGS ARKANSAS ACADEMY OF SCIENCE

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Secretary's Report

MINUTES OF THE SEVENTY-FOURTH MEETING - APRIL 1991

FIRST BUSINESS MEETING

The meeting was called to order at 11:43 by President Watson.

1. Watson called for a representative of the Local Arrangements Committee or UAF to welcome the Academy; no response.

2. Watson recognized the Historian, H.W. Robison for a statement. This is the 75th Meeting of the Academy, the 12th time in Fayetteville. Observe the display of Academy history; Robison plans to set up this display at each annual meeting and still would like to have pictures and historical sketches.

3. Watson recognized the Secretary for the distribution of the minutes of last year's meetings and opportunity for questions and corrections. Any corrections should be submitted to me Secretary in written form before the second business meeting. Secretary also requested any motions, announcements and resolutions to be submitted in written form.

4. Watson recognized the Treasurer, Robert Wiley, for distribution and explanation of the financial report. No questions or comments came forth. Watson appointed an Auditing Committee, Stan Trauth (ASU), David Saugey (USFS), and Maurice Kleve (UALR), who will examine Wiley's books and report at the second business meeting.

ARKANSAS ACADEMY OF SCIENCE

ANNUAL FINANCIAL STATEMENT

(20 MARCH 1990 TO 20 MARCH 1991)

ANNUAL MEETING 5-6 APRIL 1991
UNIVERSITY OF ARKANSAS, FAYETTEVILLE, AR

FUNDS

Balance Approved by Audit on 7 April 1990		16,863.31
Total Income (Page 2)	13,970.40	
Total Expenses (Page 3)	- 9,715.68	
Balance for the Year	4,254.72	4,254.72
TOTAL FUNDS AS OF 20 MARCH 1991		$21,118.03

DISTRIBUTION OF ACCOUNTS

Interest Bearing Checking Account (Union Bank and Trust Co., Monticello, AR)	2,797.36
Certificates of Deposit	
Dwight Moore Endowment (Heritage Federal Savings and Loan - Monticello - No. 504891 - 6.80% Interest)	1,730.68
Life Membership Endowment (Heritage Federal Savings and Loan - Monticello - No. 504883 - 6.80% Interest)	8,144.90
AAS Endowment (Heritage Federal Savings and Loan - Monticello - No. 507912 - 7.80-% Interest)	4,845.09
AAS General CD (Heritage Federal Savings and Loan - Monticello - No. 507920 - 7.80% Interest)	3,600.00
TOTAL	$21,118.03

Respectfully Submitted.

R. Wiley

Robert W. Wiley, AAS Treasurer

Page 2. Financial Statement, Arkansas Academy of Science

INCOME:	20 March 1990 to 20 March 1991		
1.	INDIVIDUAL MEMBERSHIPS		
	a. Regular	2,700.00	
	b. Sustaining	240.00	
	c. Sponsoring	90.00	
	d. Life	550.00	
	e. Associate	40.00	
		3,620.00	3,620.00
2.	INSTITUTIONAL MEMBERSHIPS		2,100.00
3.	PROCEEDINGS, LIBRARY SUBSCRIPTIONS		453.00
4.	PROCEEDINGS, MISC. SALES (UAF)		2,174.46
5.	PROCEEDINGS, PAGE CHARGES		2,750.00
6.	ANNUAL MEETING: ARKANSAS STATE UNIVERSITY - 6-7 APRIL 1990		1,640.25
7.	INTEREST		
	a. Interest Bearing Checking Account	88.35	
	b. Dwight Moore Endowment	116.78	
	c. Life Membership Endowment	604.34	
	d. AAS Endowment	73.65	
		883.12	883.12
8.	ENDOWMENT DONATIONS		
	a. Dwight Moore Endowment	125.00	
	b. AAS Endowment - Unrestricted	100.00	
		225.00	225.00
9.	MISCELLANEOUS		124.57
TOTAL INCOME			$13,970.40

Page 3. Financial Statement. Arkansas Academy of Science

EXPENSES: 20 March 1990 to 20 March 1991

1.	AWARDS		
	a. Theresa Hines (#556)	50.00	
	b. S. Alzaain (#557)	50.00	
	c. John D. Peck, Plaque - Arkansas Science Talent Search (#558)	63.60	
	d. Arkansas Junior Academy of Science (#555)	250.00	
	e. Arkansas Science Fair Association (#554)	200.00	
		613.60	613.60
2.	PROCEEDINGS		
	a. Phillips Litho (Vol. 43) (#551)	107.90	
	b. Phillips Litho (Vol. 43) (#559)	8,057.24	
	c. Linda Lee, Editorial Consultant Vol. 43 (#552)	500.00	
		8,665.14	8,665.14
3.	OFFICE EXPENSES		
	a. Secretary's Office John Rickett (#561)	248.78	
	b. Treasurer's Office Postmaster (#560)	25.00	
		273.78	273.78
4.	ANNUAL MEETING EXPENSES (ASU)		
	a. Mr. Trophy (#553)		43.24
5.	NEWSLETTERS		
	a. University of Arkansas, Forest Research (#565)		63.35
6.	DUES		
	a. National Association of Academies of Science (#564)		28.00
7.	SERVICE CHARGE		11.90
8.	MISCELLANEOUS (#562)		16.67
	TOTAL EXPENSES		$9,715.68

5. Watson recognized the *Proceedings* Editor, Harvey Barton, for a report. Individuals pick their copy of the journal and would a representative from each campus return with unclaimed copies going to that campus. Editors should gather manuscripts at the conclusion of paper sessions. Motion: (Barton; 2nd A. Johnson) the Academy appropriate $500 for editorial assistance to prepare volume 45 (1991) of the *Proceedings*.

6. Watson recognized the *Newsletter* Editor, Dick Kluender, for a report. The cost to the Academy was postage ($63.35); the Department of Forest Resources (UAM) supports the printing. Thanks R. Wiley for proofreading and J. Rickett for providing mailing labels. Motion: (Kluender; 2nd D. Saugey) the Academy appropriate $650 to support production of the *Newsletter* in case the next editor cannot find in-house support to this extent.

7. Watson recognized the Director of Science Fairs, Mike Rapp, for a report.

   a. Science Fairs: reported on the participation by students and teachers in seven regional fairs and the International Science Fair. Motion: (Rapp; 2nd A. Johnson) the Academy appropriate $320 to support the Arkansas Science Fair Association. Rapp also moved the Academy officially commend the seven regional science fair directors (2nd H. Barton) (letter attached).

   b. Junior Academy of Science (for Pat Knighten): Motion: (Rapp; 2nd H. Barton) the Academy appropriate $250 to provide scholarship awards to winners at the Junior Academy of Science Meeting later this month.

   c. Arkansas/Westinghouse Science Talent Search (for John Peck):First place winner was Christopher Brazzel, Pine Bluff High School with the paper, "The Grand Unified Field Theory", and sponsored by Mrs. Jewell Whatley. Second place winner was Ward Daniel Cook, Little Rock Central High School, with the paper, "What are the Nuclear Excited States of Neon-20?", sponsored by Mrs. Annice Steadman, Mrs. Jacqueline Dyer and Dr. Andre Rollefson. Motion: (Rapp, 2nd T. Palko) the Academy appropriate $150 to recognize the two winners of the talent search and their sponsors. Watson announced the winner at last year's Junior Academy meeting will present the paper at this meeting of the Senior Academy.

8. Watson recognized the Director of the Junior Science and Humanities Symposium, Tom Palko, for a report. The meeting was held 15-17 March, and 114 students and 35 teachers submitted 73 papers, 15 of which were selected to be presented orally. The highlight of the meeting was a four-hour barge trip on the Arkansas River sponsored by the U.S. Corps of Engineers. Last year's national competition was won by an Arkansan, Jesse Sang, Little Rock Central High School, who received a two-week trip to London, England. This year's Arkansas representative to the national competition will be Edith Apple from North Little Rock with the paper, "Hierarchy of Navigation in Red Ants."

9. Watson gave a report from the Nominating Committee; George Harp was submitted as nominee for Vice-President. Opportunity was provided for nominations from the floor, but none came.

10. Watson relayed the report from Leo Paulissen of the Biota Survey Committee. New addenda are being prepared, but none are available at this time.

11. Watson gave a report on the new composition of the Science Education Committee – 12 members, three year terms, four members rotate off each year. There will be a meeting this afternoon after the paper sessions. New members are Tom Lynch, Chair; Bonnie Moody (Henderson State University); Rudy Timmerman (Rich Mountain Community College); and Dalena Tull (University of Central Arkansas). Watson asked Lynch to read the list of the other members.

12. Motion: (Rickett; 2nd T. Palko) the Executive Committee at the Fall 1990 meeting approved the raising of "Associate" membership dues from $5 to $10. But the category name should be also be labelled as undergraduate. This will be voted on during the second business meeting.

13. Watson appointed a Resolutions Committee consisting of Robert Wright, Mike Plummer and John Sorensen.

14. Watson announced the acceptance by the Executive Committee of the invitation from the University of Central Arkansas to host the 1992 meeting. We have not received an invitation for the 1993 meeting.

15. Watson encouraged the section chairpersons to keep their paper presentations on time.

16. Watson announced that the Arkansas Science Teachers Association is meeting in conjunction with the Academy. We welcome them and hope their efforts are productive.

17. Watson, in lieu of a representative of the Local Arrangements Committee, announced the banquet. Dr. Terry Cole (NASA) will

Secretary's Report

speak after dinner. Sigma Xi is sponsoring the banquet speaker. Everyone is invited to the social hour prior to the banquet.

18. Watson reported on the background and mechanics of the "logo contest." No interest shown yet, but it is still open. Wiley knows a graphic designer who might help us design a new logo. Watson also brought some samples of logos from other states.

19. Watson called for new business and hearing none, adjourned the meeting at 12:20.

SECOND BUSINNESS MEETING

President Watson called the meeting to order at 12:10 pm.

1. Watson called for corrections to and approval of minutes from last year's business meetings. No corrections were offered, and approval was by voice vote.

2. Watson recognized Stan Trauth for a report from the Auditing Committee. The committee found the Treasurer's books in order and moved the approval of the Treasurer's report for the year immediately past. Motion carried by voice vote.

3. Watson recognized Treasurer, Robert Wiley for a follow-up on his report in the first business meeting. No further questions came, and Wiley summarized by stating the Academy's financial status is as secure as it has been in recent years. Report approved by voice vote.

4. Watson recognized Secretary, John Rickett for a re-statement of the five motions for continued support:

   a. H. Barton, editorial assistance: $500
   b. D. Kluender, *Newsletter:* up to $650
   c. M. Rapp, Science Fairs: $320
   d. M. Rapp (for P. Knighten), Junior Academy: $250
   e. M. Rapp (for John Peck), Westinghouse Talent Search: $150

   Motions approved as a group by voice vote.

5. Watson recognized the Secretary for a re-statement of the motion to raise "Associate" (Undergraduate) Membership category dues from $5 to $10. Motion passed by voice vote.

6. Watson recognized the Nominating Committee's submission of George Harp for Vice-President and opened the floor for further nominations. R. Speairs moved G. Harp be elected by acclamation (2nd H. Barton). Motion carried by voice vote.

7. Watson recognized R. Wright for a report from the Resolutions Committee, who then read the following resolutions:

   Be it resolved that: that the members of the Arkansas Academy of Science express their sincere appreciation to the faculty, staff and students of the University of Arkansas/Fayetteville for hosting our 1991 meeting. We especially thank Dr. John Hehr and his Local Arrangements Committee for all their efforts on behalf of the membership to make this meeting a success. Thanks are due to section chairs, individual presenters, faculty advisors, and judges of student papers. We also recognize the contributions of chapters of Sigma Xi and its individual members to the success of the meeting. Thanks are also extended to Robert Watson, President; Michael Rapp, President-Elect; Richard Speairs, Past-President; the remaining officers and other members of the Executive Committee and other committees of the Academy whose cooperative efforts were so apparent during the meeting. Finally we thank Dr. Terry Cole for sharing with us the truly remarkable accomplishments of planetary exploration at the Jet Propulsion Laboratory.

   Be it resolved that: the members of the Arkansas Academy of Science recognize Dr. Robbin Anderson for his dedicated service as chair of the Science Education Committee. His consistent alertness to legislative issues, government programs and regulations regarding science education has served us well. If he occasionally told us more than we wanted to hear, we probably needed to know it. Ever the gentleman, he has been our distinguished ambassador for science education. We thank him for his service.

   Be it resolved that: the members of the Arkansas Academy of Science recognize Dr. Paul Krause for his work as Director of the Junior Academy of Science. Organizing and carrying out the annual meeting is a little like being the local arrangements chair for the Academy of Science year after year. And he has done a thoroughly professional job. His contribution toward encouraging and honoring high school students and teachers has made a difference in Arkansas, and we thank him.

8. Watson announced the University of Central Arkansas will host the 1992 Academy of Science. Decision was made at the fall 1991 meeting of the Executive Committee.

9. Watson recognized the Nominating Committee; Jim Daly (UAMS), Dan England (SAU), and Walt Godwin (UAM) and thanked them for their work.

10. Watson announced no invitation has been received yet for the Academy's 1993 meeting. We usually try to plan two years in advance. He solicited an invitation.

11. Watson recognized Leo Paulissen for a follow-up report on the Biota Survey. He is currently preparing a few new lists but doesn't have any ready at the present.

12. Watson called for New Business:

    a. Announced (for H. Barton) for campus representatives to pick up unclaimed copies of the *Proceedings* and take them back with you. M. Rapp assisted in the disbursing these groups of journal copies.

    b. Watson asked if the paper judges had made their final decision yet – no.

    c. A comment from the floor pointed out that two different times publicized for the first business meeting caused some participants to miss it. President: point well taken.

    d. A comment from the floor drew attention to an error in the journal's instructions to authors page.

    e. Watson again recognized the Historian's efforts in assembling the historical display. He also reminded the membership to submit items of interest to H. Robison.

    f. Watson again recognized the Audit Committee, Resolutions Committee, Science Education Committee, and the Judging Committee (Ed Dale, Nancy McCartney, John Dixon and Jeff Demaris). Watson personally thanked the members of the Executive Committee for their contributions during the past year and particularly Mike Rapp and John Rickett.

    g. Watson recognized Mike Rapp and installed him as the new President. Rapp then presented Watson a plaque of recognition for last year's work as President. Rapp brought attention to a picture of a horsefly embossed on the plaque as representative of Watson's research interests, whereupon Watson replied with a statement about the horsefly's blood-sucking tendencies. A little levity doth lighten the spirit.

13. M. Rapp, as new President, asked new members to rise and introduce themselves as evidence that the Academy of Science is a family. He also asked life members to rise and introduce themselves. He urged action by those who are willing to facilitate the work of the Academy and continue our tradition of excellence.

14. Rapp recognized John Sorensen who issued an appeal for Academy members to volunteer to judge science fairs.

15. Betty Spears asked Rapp to introduce our President-Elect, which he did – Art Johnson.

16. Jim Fribourgh asked about the status of the logo contest – Rapp replied no response yet, but it is still open.

17. Rapp placed the meeting in recess until the results of the student paper presentations judging are available.

18. Student winners announced were Annise Evans (UAPB-undergraduate) and Gary Fuller (UALR-GIT-graduate); announced by Ed Dale. Several members simultaneously raised a point of order that two undergraduate awards (life sciences and physical sciences) should be given. The committee will meet again and resolve the issue.

19. President Rapp adjourned the meeting at 12:46 pm.

MEMBERS 1991

Roger	Abernathy	Arkansas State University	regular
Stephen R.	Addison	University of Central Arkansas	regular
Sam	Al-Zaaim	University of Arkansas at Litt	regular
Silke Hufangel	Allen	Hendrix College	regular
Robert T.	Allen	University of Arkansas at Faye	regular
Robbin C.	Anderson	University of Arkansas at Faye	Life
Cynthia	Annett	University of Arkansas at Faye	regular
John T.	Annulis	University of Arkansas at Mont	regular
Edmond J.	Bacon	University of Arkansas at Mont	Life
Robert	Bacon	University of Arkansas at Faye	regular
Claudia	Bailey	University of Arkansas at Faye	regular
Max L.	Baker	University of Arkansas/Medical	regular
Kenneth M.	Ball	El Dorado Public Schools	regular
William H.	Baltosser	University of Arkansas at Litt	regular
Gwen	Barber		regular
Harvey E.	Barton	Arkansas State University	sustaining
Adelphia M.	Basford	Henderson State University	regular
Vernon	Bates		regular
John Kenneth	Beadles	Arkansas State University	regular
Judith A.	Bean	Harmony Grove High School	sustaining
Ashley	Bean	Hendrix College	regular
John B.	Bennett	Arkansas State University	sustaining
Ann Marie	Benson	University of Arkansas/Medical	regular
Hal	Berghel	University of Arkansas at Faye	regular
C.	Bhuvaneswaran	University of Arkansas/Medical	regular
Elaine	Bickle	Northeast Louisiana State Univ	associate
George T.	Blevins	University of Arkansas/Medical	associate
Veryl	Board	Arkansas College	regular
Marilyn	Bocksanick	Arkansas Tech University	regular
Laurence J.	Boucher	Arkansas State University	regular
William R.	Bowen	University of Arkansas at Litt	regular
Robert E.	Bowling	University of Arkansas/Medical	sustaining
Leo H.	Bowman	Arkansas Tech University	regular
Patricia	Brackin	Christian Brothers College	regular
Jimmy D.	Bragg	Henderson State University	regular
Wilfred J.	Braithwaite	University of Arkansas at Litt	regular
Marge A.	Brewster	Arkansas Childrens Hospital	regular
John F.	Bridgman	University of the Ozarks	regular
Arthur V.	Brown	University of Arkansas at Faye	regular
Joseph M.	Brown	Mississippi State University	regular
Susan G.	Brown	University of Arkansas at Litt	regular
William D.	Brown	University of Arkansas at Faye	regular
Charles T.	Bryant	Water Resources of Arkansas	regular
Gaylen	Burnside	University of Arkansas at Litt	regular
Jody	Caldwell	University of Arkansas at Litt	regular
Chris	Carlton	University of Arkansas at Faye	regular
Phyllis	Chaffin	Arkansas State University	regular
Stanley L.	Chapman	University of Arkansas at Faye	regular
David	Chittenden	Arkansas State University	life
Cindy	Cisar	University of Arkansas at Faye	regular
Frances E.	Clayton	University of Arkansas at Faye	regular
Malcolm K.	Cleaveland	University of Arkansas at Faye	sustaining
Betty S.	Cochran	U.S. Forest Service	regular
Lorris G.	Cockerham	NCTR Associated Universities,	sponsoring
Richard R.	Cohoon	Arkansas Tech University	regular
Larry	Coleman	University of Arkansas at Litt	regular
R. Lilia	Compadre	University of Arkansas/Medical	regular
Robert L.	Cook	Mississippi State University	regular
Janice Lorraine	Cooper	Arkansas State University	regular
Robert M.	Cordova	Cordco Consulting	regular
Calvin	Cotton	Geographics Silk Screening Co.	sponsoring
William	Coutts	University of Arkansas at Litt	regular
Bob W.	Cowling	Malvern High School	regular
Robert M.	Crisp, Jr.	University of Arkansas at Faye	regular
Donald	Culwell	University of Central Arkansas	sustaining
Edward E.	Dale, Jr.	University of Arkansas at Faye	sustaining
Fred	Dalske	University of Central Arkansas	regular
James J.	Daly	University of Arkansas/Medical	regular
James T.	Daniels	Southern Arkansas University/T	regular
Jerry A.	Darsey	University of Arkansas at Litt	regular
Pat	Darsey	Holy Souls Catholic School	regular
Stanley N.	David	Arkansas State University	regular
David L.	Davies	University of Arkansas/Medical	sponsoring
Leo Carson	Davis	Southern Arkansas University	sponsoring
Jeffery R.	Demarest	University of Arkansas at Faye	regular
Robert H.	Dilday	University of Arkansas at Faye	life
Ronald H.	Doran	Harding University	regular
Peggy Rae	Dorris	Henderson State University	regular
Robert H.	Doster	University of Arkansas at Faye	regular
Robert L.	Douglas	Memphis State University	regular
Marian	Douglas	University of Arkansas at Litt	regular
Mark	Draganjac	Arkansas State University	life
Benjamin T.	Duhart	University of Arkansas at Pine	regular
David	Dussourd	University of Central Arkansas	regular
Jim	Edson	University of Arkansas at Mont	sponsoring
Rudolph J.	Eichenberger	Southern Arkansas University	regular
Thomas K.	Ekman	Southern Arkansas University	regular
Hudson B.	Eldridge	University of Central Arkansas	regular
Robert	Engelken	Arkansas State University	regular
Daniel R.	England	Southern Arkansas University	life
Don	England	Harding University	regular
Lawana	England-Whaley	Arkansas State University	sponsoring
Carole	Engle	University of Arkansas at Pine	regular
Claude E.	Epperson	University of Arkansas/Medical	regular
Ray	Erickson	U.S. Department of Agriculture	regular
William L.	Evans	University of Arkansas at Faye	Life
Wilbur W.	Everett	Ouachita Baptist University	regular
E. Kim	Fifer	University of Arkansas/Medical	regular
Sheldon	Fitzpatrick	University of Arkansas at Pine	sustaining
M. Doug	Fletcher	Riceland Foods Inc. (ASU)	regular
Thomas H., III	Fletcher	University of Arkansas/Medical	associate
E. P. (Perk)	Floyd	U.S. Public Health Service (re	regular
Thomas L.	Foti	Natural Heritage Commission	regular
Paul B.	Francis	University of Arkansas at Mont	regular
Winefred	Fraser	Arkansas College	regular
Kenneth	Freiley	University of Central Arkansas	regular
James H.	Fribourgh	University of Arkansas at Litt	Life
Arthur	Fry	University of Arkansas at Faye	Life
Gary	Fuller	University of Arkansas at Litt	regular
Kamesh	Gadepally	University of Arkansas at Litt	regular
Charlie	Gagen	Arkansas Tech University	regular
Jack	Gaiser	University of Central Arkansas	regular
Diana	Garland	Memphis State University	regular
Joe P.	Gentry	Arkansas Science & Technology	regular
Michael	George	Arkansas State University	regular
Collis R.	Geren	University of Arkansas at Faye	Life
John	Giese	Ark. Dept. of Pollution Contro	Life
Loren J.	Giesler	Chadron State College	associate
John T.	Gilmour	University of Arkansas at Faye	regular
Mattie	Glover	University of Arkansas at Pine	regular
David	Goad	University of Arkansas at Litt	associate
Walter E.	Godwin	University of Arkansas at Mont	Life
Kevin D.	Golden	University of Arkansas at Faye	associate
William E.	Gran	University of Arkansas at Litt	regular
Wayne L.	Gray	University of Arkansas/Medical	regular
Robert A.	Green	Mississippi State University	regular
Edmond E.	Griffin	University of Central Arkansas	regular
Gaston	Griggs	John Brown University	regular
Mark	Gross	University of Arkansas at Litt	regular
Peggy	Guccione	University of Arkansas at Faye	regular
Joe M.	Guenter	University of Arkansas at Mont	Life
Rao P.	Gullapalli	University of Arkansas at Litt	regular
Paul D.	Gwinup	Arkansas State University	regular
Bruce	Haggard	Hendrix College	regular
Jeffrey R.	Hammersley	UAMS/UALR	regular
Earl L.	Hanebrink	Arkansas State University	regular
B. J.	Hankins	University of Arkansas at Faye	regular
Richard H.	Hanson	University of Arkansas at Litt	regular
Joyce M.	Hardin	Hendrix College	regular
George L.	Harp	Arkansas State University	sponsoring
Phoebe A.	Harp	Arkansas State University	sponsoring
John L.	Harris	Arkansas Highway & Transportat	regular
Michael J.	Harvey	Tennessee Tech University	regular
Roger M.	Hawk	University of Arkansas at Litt	regular
Gary A.	Heidt	University of Arkansas at Litt	Life
Ronnie	Helms	University of Arkansas at Faye	Life
Christopher C.	Hemann	Hendrix College	associate
Mustfa	Hemmati	Arkansas Tech University	regular
Burton	Henderson	University of Arkansas at Litt	regular
Larry	Hinck	Arkansas State University	regular
Dean	Hirschi	University of Central Arkansas	regular
Maxine R.	Hite		regular
Lisa J.	Hlass	U.S. Corps of Engineers	regular
Howard	Hodges	University of Arkansas at Litt	regular
Kay	Holtman	University of Arkansas at Litt	regular
William G.	Hood	University of Arkansas at Litt	regular

Secretary's Report

Lester C.	Howick	University of Arkansas at Faye	sponsoring
Arthur	Hoyt, Jr.	University of Central Arkansas	regular
Feng Hou	Huang	University of Arkansas at Faye	regular
W. Keith	Hudson	University of Arkansas at Litt	regular
Jim	Huey	University of Arkansas at Mont	regular
Julie	Huggins	Union University	regular
Charles A.	Hughes	Arkansas State University	regular
Paul	Hunkapiller	Phillips County Community Coll	regular
Philip E.	Hyatt	University of Arkansas at Faye	regular
Joseph U.	Igietseme	University of Arkansas/Medical	regular
Duane	Jackson	University of Arkansas at Litt	regular
M. D.	Jalaluddin	University of Arkansas at Pine	regular
Douglas	James	University of Arkansas at Faye	Life
David	Jimerson	Arkansas State University	regular
Arthur A.	Johnson	Hendrix College	Life
James E.	Johnson	University of Arkansas at Faye	regular
Michael I.	Johnson	Hettleton High School	regular
Perry Max	Johnston	University of Arkansas at Faye	sustaining
Suzanne M.	Jones	Arkansas State University	regular
Jay	Justice	Ark. Dept. Pollution Control &	regular
Ragupathy	Kannan	University of Arkansas at Faye	regular
Alvan A.	Karlin	University of Arkansas at Litt	regular
Mark	Karnes	The Ross Foundation	regular
Philip L.	Kehler	University of Arkansas at Litt	regular
Raj V.	Kilambi	University of Arkansas at Faye	regular
Robert T.	Kirkwood	University of Central Arkansas	Life
Maurice G.	Kleve	University of Arkansas at Litt	regular
Richard	Kluender	University of Arkansas at Mont	regular
Roger E., III	Koeppe	University of Arkansas at Faye	regular
Richard A.	Komoroski	University of Arkansas/Medical	regular
Randall A.	Kopper	Hendrix College	regular
Walter A.	Korfmacher	National Ctr. for Toxicologica	regular
Timothy	Kral	University of Arkansas at Faye	regular
Paul	Krause	University of Central Arkansas	regular
Jack C.	Kreie	Fayetteville Public Schools	regular
Timothy T.	Ku	University of Arkansas at Mont	regular
Forrest E.	Lane	University of Arkansas at Faye	regular
Norman	Lavers	Arkansas State University	regular
Linda A.	Lee	Pocahontas Middle School	regular
Jerry L.	Linnstaedter	Arkansas State University	regular
J. Mitchell	Lockhart	University of Arkansas at Faye	regular
Thomas J.	Lynch	University of Arkansas at Litt	regular
Siripong	Malasri	Christian Brothers University	regular
Ali	Mansouri	University of Arkansas/Medical	regular
Mitchell K.	Marks	Arkansas State University	regular
Daniel L.	Marsh	Henderson State University	sustaining
Michael L.	Martin	Arkansas State University	associate
Herbert M.	Matthews	Henderson State University	regular
Robin	Matthews	University of Arkansas at Litt	associate
Donald R.	Mattison	University of Pittsburgh	Life
M. K.	Mazumder	University of Arkansas at Litt	regular
Chris T.	McAllister	Veterans Affairs Medical Cente	regular
Russell B.	McAllister	Arkansas State University	regular
Nancy Glover	McCartney	University of Arkansas at Faye	regular
Clark W.	McCarty	Ouachita Baptist University (r	regular
Rose	McConnell	University of Arkansas at Pine	regular
Roland E.	McDaniel	FTN Associates, Ltd.	sustaining
V. Rick	McDaniel	Arkansas State University	regular
Paul	McLeod	University of Arkansas at Litt	regular
Clarence E.	McMahon	(Hendrix College)	regular
Dennis W.	McMasters	Henderson State University	regular
Harlan	McMillan	Arkansas Tech University	regular
Pamela J.	McMillan	University of Arkansas/Medical	associate
Tammie	McRae	National Ctr. for Toxicologica	regular
Rahul	Mehta	University of Central Arkansas	regular
Richard	Meyer	University of Arkansas at Faye	regular
Lawrence A.	Mink	Arkansas State University	regular
Angel	Mintz	University of Arkansas at Faye	associate
Richard S.	Mitchell	Arkansas State University	regular
Sanjay K.	Mitra	University of Arkansas at Litt	regular
Roberta A.	Mittelstaedt	National Center for Tox. Resea	regular
Clementine	Moore		Life
Leland F.	Morgans	University of Arkansas at Litt	regular
Stephen R.	Moulton, III	University of North Texas	regular
Michael	Murphy	Arkansas State University	regular
Joseph C.	Neal	University of Arkansas at Faye	regular
Nathaniel	Nehus	Ark. Dept. Pollution Control &	regular
Thomas	Nelson	Arkansas Tech University	regular
W. Donald	Newton	Arkansas State University	regular
William F.	Nicholson	University of Arkansas at Mont	regular
Alex R.	Nisbet	Ouachita Baptist University	sustaining
Joe	Nix	Ouachita Baptist University	regular
Gaylord M.	Northrop	University of Arkansas at Litt	regular
Timothy J.	O'Brien	University of Arkansas/Medical	regular
Larry A.	Olson	Arkansas State University	regular
Derrick M.	Oosterhuis	University of Arkansas at Faye	regular
Tom	Palko	Arkansas Tech University	Life
Bryan D.	Palmer	Henderson State University	regular
Leo J.	Paulissen	University of Arkansas at Faye	regular
Mark A.	Paulissen	Slippery Rock University	regular
John E.	Pauly	University of Arkansas/Medical	regular
Forrest	Payne	FTN Associates	regular
Carol J.	Peck	University of Arkansas at Litt	Life
James H.	Peck	University of Arkansas at Litt	Life
John D.	Peck	University of Central Arkansas	regular
Bill	Pell	U.S. Forest Service	regular
Carlos H.	Pennington	USAE Waterways Experiment Stat	regular
Mark A.	Pippenger	University of Arkansas/Medical	regular
Albert B.	Pittman	Arkansas Natural Heritage Comm	regular
Michael V.	Plummer	Harding University	regular
Roberta Dee	Pond		regular
Donna	Porter	University of Arkansas at Faye	associate
Gayle L.	Pounds	University of Arkansas at Pine	regular
Ervin W.	Powell	University of Arkansas/Medical	sustaining
Harold	Pray	University of Central Arkansas	regular
Alan D.	Price	Ark. Dept. Pollution Control &	sustaining
Mazo	Price	University of Arkansas at Pine	regular
Denver L.	Prince	University of Central Arkansas	regular
S.	Ramaprasad	University of Arkansas/Medical	regular
Michael W.	Rapp	University of Central Arkansas	Life
Jeff H.	Rettig	George Washington National For	regular
Ruby S.	Reynolds	University of the Ozarks	regular
Edward L.	Richards	Arkansas State University	regular
John D.	Rickett	University of Arkansas at Litt	Life
Thomas W.	Rimmer	University of Arkansas at Litt	regular
Johnnie C.	Roberts	Arkansas State University	regular
Henry W.	Robison	Southern Arkansas University	Life
Marty	Roop	University of Arkansas/Medical	regular
Peggy	Root	Southern Arkansas University	regular
Perry C.	Rothrock, III	University of Arkansas/Medical	regular
Marsha	Rowe	Stamps High School	regular
Louise	Russert-Kraemer	University of Arkansas at Faye	regular
Rosa I.	Sanchez	University of Arkansas/Medical	regular
Subhendra N.	Sarkar	University of Arkansas/Medical	regular
David A.	Saugey	U.S. Forest Service	Life
Andrew C.	Scallet	Nat. Center for Toxicological	regular
John A.	Sealander	University of Arkansas at Faye	regular
Leo	Setian	John Brown University	regular
Frank L.	Setliff	University of Arkansas at Litt	regular
Larry	Seward	John Brown University	regular
Stephen A.	Sewell	USDA-Soil Conservation Service	Life
Elwood B.	Shade	University of Arkansas at Mont	associate
Mostafa	Shahriar	Southern Arkansas University	regular
Ali U.	Shaikh	University of Arkansas at Litt	regular
Robert B.	Shanks	University of Arkansas at Litt	regular
Paul C.	Sharrah	University of Arkansas at Faye	regular
William H.	Shepherd	Arkansas Natural Heritage Comm	regular
Samuel	Siegel	University of Arkansas at Faye	regular
Dewey H.	Sifford	Arkansas State University	regular
Robert	Sims	University of Arkansas at Litt	regular
Tom	Slatton	NLR High School, East Campus	regular
Edwin B.	Smith	University of Arkansas at Faye	regular
Kenneth L.	Smith	Governor's Office (attache)	regular
Kimberly G.	Smith	University of Arkansas at Faye	regular
Roy J.	Smith, Jr.	U.S.D.A./Univ. of Arkansas	regular
L. Dale	Snow	Louisiana Tech University	regular
Clifford S.	Snyder	University of Arkansas at Faye	regular
David G.	Snyder	University of Arkansas at Mont	regular
W. Sherman	Snyder	Arkansas Natural Heritage Comm	regular
John R.	Sorensen	University of Arkansas/Medical	regular
Betty H.	Spears	Ouachita Mtns. Biological Stat	Life
Richard K.	Spears	Ouachita Mtns. Biological Stat	Life
Stan	Speight	Arkansas State Parks Departmen	regular
Frederick W.	Spiegel	University of Arkansas at Faye	regular
Richard W.	Standage	U.S. Forest Service	regular
Kenneth F.	Steele	University of Arkansas at Faye	regular
Denise	Steigerwald	University of Arkansas at Mont	regular
Ann	Steinmeier	Baptist Medical Center	regular
T. W.	Steward	Arkansas State University	regular
Eric	Sundell	University of Arkansas at Mont	sustaining
Mark	Sutherland	Hendrix College	regular
Keith	Sutton,	Hendrix College	regular
Phil	Tappe	University of Arkansas at Mont	regular
William S.	Taylor	University of Central Arkansas	regular
Sandy	Tedder	University of Arkansas at Faye	regular
George E.	Templeton	University of Arkansas at Faye	Life
Lyell	Thompson	University of Arkansas at Faye	regular
Dan	Timmerman	Arkansas State University	regular
Lorraine	Timmerman	Newark High School	regular
Rudy	Timmerman	Rich Mountain Community Colleg	regular
Les	Torrans	University of Arkansas at Pine	regular
Stanley E.	Trauth	Arkansas State University	regular
Gary	Tucker	U.S. Forest Service	Life
Renn	Tumlison	Henderson State University	regular
Tom	Turner	Ouachita Baptist University	regular
Richard K.	Ulrich	University of Arkansas at Faye	regular
Victor K.	Vere	Arkansas Tech University	regular
Tito	Viswanathan	University of Arkansas at Litt	regular
David L.	Vosburg	Arkansas State University	regular
George H.	Wagner	University of Arkansas at Faye	regular
Ernest M.	Walker	UAMS/ McClellan VA Hospital	regular
Richard B.	Walker	University of Arkansas at Pine	regular
Stephen A.	Walker	Arkansas Tech University	regular
David L.	Wankum	University of Arkansas at Litt	regular
Robert L.	Watson	University of Arkansas at Litt	sustaining
James O.	Wear	Veterans Administration Medica	sustaining
David	Weaver	Arkansas State University	regular
Karen	Weaver	University of Central Arkansas	regular
Jerry	Webb	University of Arkansas at Mont	regular
G. J.	Weidemann	University of Arkansas at Faye	regular
David	Wennerstrom	University of Arkansas/Medical	regular
Delores	Wennerstrom	Pulaski Academy	associate
Dora	Weyer	University of Arkansas at Faye	associate
Jonathan	White	Memphis State University	regular
James L.	Wickliff	University of Arkansas at Faye	Life
T. Bentley	Wigley	University of Arkansas at Mont	regular
Robert W.	Wiley	University of Arkansas at Mont	Life
J. D.	Wilhide	Arkansas State University	regular
William M.	Willingham	University of Arkansas at Pine	regular
Rebecca L.	Willis	Southern Arkansas University	regular
Jason	Willis	University of Arkansas at Litt	associate
Edmond W.	Wilson, Jr.	Harding University	regular
Duane C.	Wolf	University of Arkansas at Faye	regular
Heather L.	Woolverton	University of Central Arkansas	regular
Robert D.	Wright	University of Central Arkansas	regular
Chaoping	Wu	University of Arkansas at Litt	regular
William V.	Wyatt	Arkansas State University	regular
Karen L.	Yaich	Arkansas Game & Fish Commissio	regular
Chia C.	Yang	Arkansas Tech University	regular
Dominic T.	Yang	University of Arkansas at Litt	regular
J. Lyndal	York	University of Arkansas/Medical	regular
David A.	Young	Fayetteville Public Schools	regular

PROGRAM
Arkansas Academy of Science

Seventy-fifth Annual Meeting

5-6 April, 1991

University of Arkansas at Fayetteville

Fayetteville, Arkansas

Meeting concurrently with sessions of

The Collegiate Academy of Science

Friday, 5 April, 1991

Registration
Executive Committee
First Business Meeting
Exhibits and Refreshments

Paper Sessions

Students I - Botany/Ecology/Aquatics
Botany I/ Biomedical
Microbiology
Physics/Engineering I
Fish Biology

Hospitality Hour
Sponsored by University of Arkansas for Medical Sciences
Banquet
Speaker: Dr. Terry Cole
Beauty on a Planetary Scale: A Summary of What Has Been Learned Through Remote Sensing of the Planets

Saturday, 6 April, 1991

Registration
Exhibits and Refreshments
Second Business Meeting

Paper Sessions

Students II - Vertebrates/Microbiology/Biomedical/ Chemistry/Engineering
Botany II/Science Education
Aquatics/Invertebrates
Chemistry/Engineering II
Vertebrates/Geology

Sigma Xi Breakfast

The traditional Sigma Xi Breakfast will be held at the Ozark Mountain Smokehouse on Dickson Street on Saturday, 6 April, 1991, beginning at 7:00 am.

SECTION PROGRAMS

[*Undergraduate student Competition **Graduate Student Competition]

Friday, April 5, 1991

STUDENTS I: BOTANY/ECOLOGY/AQUATICS

Chairperson: Dr. E.E. Dale, University of Arkansas, Fayetteville

*FLORA OF THE ST. FRANCIS NATIONAL FOREST.
Celia Ison and Don Culwell, Department of Biology, University of Central Arkansas, Conway, AR 72032.

**CYANOBACTERIA OF RICE FIELDS IN CENTRAL ARKANSAS.
Laura K. Simpson, Joyce M. Hardin and Kelly K. Agnew, Department of Biology, Hendrix College, Conway, AR 72032.

*A SURVEY OF THE VASCULAR FLORA OF BAXTER COUNTY, ARKANSAS.
Philip E. Hyatt, Department of Biological Sciences, University of Arkansas, Fayetteville, AR 72701.

*EVALUATION OF *Aposphaeria amaranthi* AS A BIOHERBICIDE FOR PIGWEED *(Amaranthus spp.)*.
Angel Mintz and G.J. Weidemann, Department of Plant Pathology, PTSC217, University of Arkansas, Fayetteville, AR 72701.

*A CLADISTIC ANALYSIS OF EIGHT SPECIES OF *Lemna* (LEMNACEAE).
Kevin D. Golden and F.W. Spiegel, Department of Biological Sciences, University of Arkansas, Fayetteville, AR 72701.

**STUDY ON *Taxodium-Nyssa* SWAMP IN INDEPENDENCE COUNTY, ARKANSAS.
Kevin Rouse and Lisa Moxley, Natural Sciences and Mathematics Program, Arkansas College, Batesville, AR 72501 and Winifred Fraser, University of Texas School of Medicine at Galveston, TX 77550.

**AN ANALYSIS OF STOMACH CONTENTS OF THE OUACHITA MADTOM *(Noturus lachneri)* in Streams of the Upper Saline Drainage.
Tim M. Patton and Mark L. Zornes, Fish and Wildlife Biology Program, Arkansas Tech University, Russellville, AR 72801.

**AN ECOLOGICAL ANALYSIS OF THE INTERTIDAL ZONE OF APPLEDORE ISLAND IN THE ISLES OF SHOALS, GULF OF MAINE.
Eric Haenni and Brian Segool, Department of Biology, Hendrix College, Conway, AR 72032.

*THE EFFECTS OF TRANSFORMATION OF PATHOGENICITY ON *Colletotrichum gloeosporioides* F.SP. *malvae*.
C.L. Trout and D.O. TeBeest, Department of Plant Pathology, University of Arkansas, Fayetteville, AR 72701.

**VERIFICATION OF REPRODUCTIVE PERIODICITY OF *Corbicula fluminea*, THE ASIATIC CLAM, IN THE SALINE RIVER, SALINE COUNTY, ARKANSAS.
Diana L. Saul and John D. Rickett, Department of Biology, University of Arkansas at Little Rock, Little Rock, AR 72204.

THE EFFECT OF FLOODING ON THE WATER QUALITY OF LAKE CATHERINE THREE YEAR COMPARISON.
Grace Velasco, Lakeside High School, 4429 Malvern Rd., Hot Springs, AR 71901.

*A SYNOPSIS OF THE NOTONECTIDAE OF ARKANSAS.
Stephen W. Chordas IIIand George L. Harp, Department of Biological Sciences, Arkansas State University, AR 72467.

**PRELIMINARY SCANNING ELECTRON MICROSCOPY OBSERVATIONS ON THE ORIGIN AND MORPHOLOGY OF CALLUS INDUCED FROM CULTIVATED RICE 'TEBONNET' SEEDS.
S.Wofford, M. Kleve, B. Wagner, B. Good and J. Peck, Department of Biology, University of Arkansas at Little Rock, Little Rock, AR 72204 and R. Dilday, USDA-ARS, P.O. Box 287, Stuttgart, AR 72160.

**PRELIMINARY OBSERVATIONS ON CALLUS INDUCTION AND PROTOPLAST ISOLATION FROM CULTIVATED RICE 'TEBONNET'.
B. Wagner, B. Good, S. Wofford, M. Kleve and J. Peck, Department of Biology, University of Arkansas at Little Rock, Little Rock, AR 72204 and R. Dilday, USDA-ARS, P.O. Box 287, Stuttgart, AR 72160.

BOTANY I/BIOMEDICAL

Chairman: Dr. J.W. Wickliff, University of Arkansas, Fayetteville

A FLORISTIC SURVEY OF THE MOIST SOIL UNITS AT HOLLA BEND NATIONAL WILDLIFE REFUGE.
Stephen A. Walker and George P. Johnson, Department of Biological Sciences, Arkansas Tech University, Russellville, AR 72801.

FINAL REPORT ON FIVE-YEAR STUDY OF *Geocarpon minimum* AT WARREN PRAIRIE NATURAL AREA.
William M. Shepherd, Arkansas Natural Heritage Commission, Suite 200, The Heritage Center, 225 East Markham, Little Rock, AR 72201, Charles R. Preston, Department of Biology, University of Arkansas at Little Rock, 2801 S. University Ave., Little Rock, AR72204 (current address: Department of Zoology, Denver Museum of Natural History, 2001 Colorado Boulevard, Denver, Colorado 80205) and Robert Steinauer, The Arkansas Nature Conservancy, 300 Spring Building, Suite 717, Little Rock, AR 72201.

NEW BOTANIC DISCOVERIES IN THE OUACHITA MOUNTAIN REGION.
Vernon Bates, Consulting Botanist, P.O. Box 1473, Mena, AR 71953 and Albert B. Pittman, South Carolina Heritage Trust, P.O. Box 167, Columbia, SC 29202.

VASCULAR FLORA OF PERRY COUNTY, ARKANSAS.
Donald E. Culwell, Department of Biology, University of Central Arkansas, Conway, AR 72032.

KENAF – A POTENTIAL NEW CROP FOR ARKANSAS.
Lyell Thompson, Department of Agronomy, University of Arkansas, Fayetteville, AR 72701.

SMALL-HEADED PIPEWORT *(Eriocaulon kornickiamum)* (ERIOCAULACEAE) IN ARKANSAS.
Gary E. Tucker, Ozark-St. Francis National Forest, Russellville, AR 72801.

ANTHOCYANINS OF THE BIRD-FOOT VIOLET, *Viola pedata*.
Forrest E. Lane, Department of Biological Sciences, University of Arkansas, Fayetteville, AR 72701.

GEOTROPISM/GRAVITROPISM: FACT AND FANCY.
Forrest E. Lane, Department of Biological Sciences, University of Arkansas, Fayetteville, AR 72701.

A CROSS-SECTIONAL STUDY OF THE POSSIBLE HEALTH BENEFITS OF THREE TYPES OF EXERCISE REGIMENS.
L.F. Morgans and A.M. Johnson, Departments of Biology and Mathematics and Statistics, University of Arkansas at Little Rock, Little Rock, AR 72204.

LOCALIZATION OF AEROSOL DEPOSITION IN A SYMMETRICAL LUNG MODEL.

Sam Al-Zaaim, David L. Wankum, Department of Electronics and Instrumentation. University of Arkansas at Little Rock, Little Rock, AR 72204, and Jeff R. Hammersley, UAMS - Pulmonary Department, 4301 W. Markham, Little Rock, AR 72204.

MUTAGENICITIES OF HYDANTOIN SUBSTITUTED NITROAROMATIC COMPOUNDS IN *Salmonella typhimurium*.

E. Kim Fifer and Cheri Greer, Department of Biopharmaceutical Sciences, College of Pharmacy, University of Arkansas for Medical Sciences, Little Rock, AR 72205.

MUTAGENICITY OF DANTROLENE AND ITS METABOLITES IN *Salmonella*.

E. Kim Fifer, College of Pharmacy, University of Arkansas for Medical Sciences, Little Rock, AR 72205 and Bruce S. Hass, Division of Comparative Toxicology, National Center for Toxicological Research, Jefferson, Arkansas 72079.

MICROBIOLOGY

Chairman: Dr. T. A. Kral, University of Arkansas, Fayetteville

EFFECTS OF SURFACE-ACTIVE AGENTS ON TISSUE ATTACHMENT OF *Sallmonella typhimurium*.

D.L. Lattin, P.J. Breen, C.M. Compadre, E.K. Fifer and H. Salari, College of Pharmacy, University of Arkansas for Medical Sciences, Little Rock, AR 72205.

ISOLATION AND POLYPEPTIDE CHARACTERIZATION OF SIMIAN VARICELLA VIRUS.

Thomas M. Fletcher IIIand Wayne Gray. Department of Microbiology and Immunology, University of Arkansas for Medical Sciences, Little Rock, AR 72205.

VESICULAR ADSORPTION SITES ON THE LATERAL EDGES OF *Simonsiella steedae*.

Fatimah A. Nahhas, Lawrence W. Hinck and W. Donald Newton, Department of Biological Sciences, Arkansas State University, State University, AR 72467.

ADENOSINE TRIPHOSPHATASE (ATPase) LOCALIZATIONS ALONG THE EXTRACELLULAR FIBRILLAR LAYER OF *Simonsiella steedae*.

Fatimah A. Nahhas, Lawrence H. Hinck and W. Donald Newton, Department of Biological Sciences, Arkansas State University, State University, AR 72467.

IDENTIFICATION OF A 60 KILODALTON IMMUNOREACTIVE RECOMBINANT *Brucella* PROTEIN AS A HEAT SHOCK PROTEIN HOMOLOG.

Michelle L. Price, R. Martin Roop II and Bruce Dunn, University of Arkansas for Medical Sciences, Little Rock, AR 72205 and Gerhardt G. Schurig, Virginia-Maryland Regional College of Veterinary Medicine, Blacksburg, VA 24061.

SIMIAN VARICELLA VIRUS AND VARICELLA ZOSTER VIRUS SHARE SIMILAR DNA STRUCTURES AND COLINEAR GENOMES.

Carla Y. Pumphrey, Thomas M. Fletcher and Wayne L. Gray, Department of Microbiology and Immunology, University of Arkansas for Medical Sciences, Little Rock, AR 72205.

USING VIRUSES TO EXAMINE SOIL TREATMENT OF SEPTIC TANK EFFLUENT.

Mark Gross, Jenna Hestir, Department of Electronics and Instrumentation, University of Arkansas at Little Rock, Little Rock, AR 72204; Duane C. Wolf and E. Moye Rutledge, Department of Agronomy, University of Arkansas, Fayetteville, AR 72701.

ENHANCED GROWTH OF *Bordetella avium* IN THE TISSUE CULTURE MEDIUM RPMI 1640.

Eric D. Howard, Kenneth C. Powell and Timothy A. Kral, Department of Biological Sciences, University of Arkansas, Fayetteville, AR 72701.

PRODUCTION AND ISOLATION OF A RECOMBINANT BACULOVIRUS CONTAINING THE GENE FOR THE HUMAN PROTEIN TYROSINE KINASE p56lck.

Stuart Wright, Box 3711, Hendrix College, Conway, AR 72032 and James M. Trevillyan, Texas Tech University School of Medicine, 1400 Wallace Boulevard, Amarillo, TX 79106.

PHOTOREACTIVATION OF UV-INDUCED DAMAGE IN G1 PHASE XENOPUS CELLS THAT LEADS TO SISTER CHROMATID EXCHANGES AND CELL DEATH.

Dawn Laswell, Jennifer Barber and Gaston Griggs, Department of Biology, John Brown University, Siloam Springs, AR 72761.

PHYSICS/ENGINEERING I

Chairman: Dr. R.M. Hawk, University of Arkansas, Little Rock

DIFFUSION OF MUONIC DEUTERIUM IN D2 GAS.

Heather L. Woolverton, University of Central Arkansas, Conway, AR 72032.

K-SHELL IONIZATION MEASUREMENTS FOR LIGHT INCIDENT IONS.

Rahul Mehta, Department of Physics, University of Central Arkansas, Conway, AR 72032.

A NEW APPROACH TO THE SOLUTION OF THE ISING MODEL.

Michael George, Department of Computer Science, Mathematics and Physics, Arkansas State University, State University, AR 72467.

HOMOGENEOUS FUNCTIONS IN THERMODYNAMICS.

Stephen R. Addison, Department of Physics, University of Central Arkansas, Conway, AR 72032.

XRF AND FT-IR REFLECTANCE ANALYSIS OF GREASE ON STEEL.

Hudson B. Eldridge, Department of Physics, and Michael W. Rapp, Department of Chemistry, University of Central Arkansas, Conway, AR 72032.

ELECTRICAL BREAKDOWN OF GASES; HISTORICAL BACKGROUND AND SOLUTIONS.

Mostafa Hemmati Department of Physics, Arkansas Tech University, Russellville, AR 72801.

EARTHRISE ON THE MOON.

Dean Hirschi, Department of Physics and Astronomy, University of Central Arkansas, Conway, AR 72032.

MICROWAVE SOIL STERILIZATION USED FOR PLANT SEEDLINGS.

Rudolph J. Eichenberger, Department of Physical Science and Technology, Southern Arkansas University, Magnolia, AR 71753.

ELECTROCHEMICAL DEGRADATION OF 2,2; DICHLORO DIPHENYL AT A RUTHENIUM DIOXIDE ELECTRODE.

G. Fuller, D. Miller, B. Miller, R. Hawk and R. Brower, Department of Electronics and Instrumentation, University of

Arkansas at Little Rock, Little Rock, AR 72204.

PROPERTIES OF (RUTILE) Ru02 COATINGS.
Kamesh V. Gadepally, David N. Patangia* and Roger M. Hawy, Department of Electronics and Instrumentation, University of Arkansas at Little Rock, Little Rock, AR 72204 and *Senior, Central High School, Little Rock, AR 72004.

DOUBLE TUNED COSINE COIL FOR NMR IMAGING/SPECTROSCOPY.
Rao P. Gullapalli, Picker International Inc., 5500 Avion Park Drive, Highland Heights, OH 44143; Dikoma P. Shungu, Department of Radiology, John Hopkins School of Medicine, Baltimore, MD 21205; and Roger M. Hawk, Department of Electronics and Instrumentation, University of Arkansas at Little Rock, Little Rock, AR 72204.

ANN; A SET OF EDUCATIONAL NEURAL NET SIMULATORS.
Siripong Malasri, Christian Brothers University, Memphis, TN 38104 and Stanley P. Franklin, Memphis State University, Memphis, TN 38152.

FISH BIOLOGY

Chairman: Dr. R. Kilambi, University of Arkansas, Fayetteville

UNDERWATER OBSERVATIONS OF HABITAT USE PATTERNS IN BASS AND SUNFISH IN OZARK IMPOUNDMENTS.
E.D. Dibble and C.A. Annett, Arkansas Cooperative Fish and Wildlife Research Units, Department of Biological Sciences, University of Arkansas, Fayetteville, AR 72701.

BEHAVIOR AND MICROHABITAT USE PATTERNS OF BASS IN CHANNELIZED AND NATURAL RIVERS.
C.A. Annett, Arkansas Cooperative Fish and Wildlife Research Unit, Department of Biological Sciences, University of Arkansas, Fayetteville, AR 72701.

FIELD AND LABORATORY ANALYSIS OF THERMAL PREFERENDA OF LARGEMOUTH BASS FROM THERMALLY ENRICHED FLINT CREEK COOLING RESERVOIR.
M.L. Galloway, Department of Science, Northwest Arkansas Community College, Rogers, AR 72756 and R.V. Kilambi, Department of Zoology, J. William Fulbright College of Arts and Sciences, University of Arkansas, Fayetteville, AR 72701.

HYPERINFECTION OF SMALLMOUTH BASS *(Micropterous dolomieui)* BY THE TREMATODE *Clinostomum marginatum* ("YELLOW GRUB").
James J. Daly, Bruce DeYoung and Terry L. Hostetler, Department of Microbiology and Immunology, University of Arkansas for Medical Sciences, Little Rock, AR 72205.

EVALUATING METHODS OF ESTIMATING SMALLMOUTH BASS IN ARKANSAS GAME AND FISH COMMISSION NURSERY PONDS.
James E. Johnson, Mitzi Pardew and Darrel Bowman, Arkansas Cooperative Fish and Wildlife Research Unit, Fayetteville, AR 72701.

BIOLOGY OF *Erimystax dissimilis* (PISCES : CYPRINIDAE) IN THE WHITE RIVER DRAINAGE, ARKANSAS.
John L. Harris, Environmental Division, Arkansas Highway and Transportation Department, P.O. Box 2261, Little Rock, AR 72203.

DISTRIBUTION AND HABITAT OF THE YELLOWCHEEK DARTER *(Etheostoma moorei)* IN THE SOUTH FORK OF THE LITTLE RED RIVER IN ARKANSAS.
Lisa J. Hlass, 511 S. Denver, Russellville, AR 72801.

ASPECTS OF THE REPRODUCTIVE LIFE HISTORY OF THE PALEBACK DARTER, *Etheostoma pallididorsum*.
John L. Harris, Arkansas Highway and Transportation Department: Environmental Division, P.O. Box 2261, Little Rock, AR 72203; Henry W. Robinson, School of Science and Technology, Southern Arkansas University, Magnolia, AR 71753; and Betty G. Cochran, USForest Service, P.O. Box 369, Glenwood, AR.

Saturday, April 6, 1991

STUDENTS II: VERTEBRATES/MICROBIOLOGY/BIOMEDICAL/CHEMISTRY/ENGINEERING

Chairman: Dr. E.E. Dale, University of Arkansas, Fayetteville

*RED-COCKADED WOODPECKER HOME RANGE SIZES IN THE SHORTLEAF PINE FORESTS OF WESTCENTRAL ARKANSAS.
Robert H. Doster, Department of Biological Sciences, University of Arkansas, Fayetteville, AR 72701

*USE OF RESTRICTED CAVITIES BY RED-COCKADED WOODPECKERS.
Barbara Raulston, Arkansas Cooperative Fish and Wildlife Research Unit, Department of Biological Sciences, University of Arkansas, Fayetteville, AR 72701.

*GEOGRAPHIC VARIATION IN THE TYPE A AND B SONGS OF THE NORTHERN PARULA.
Michael D. Bay, Department of Biological Sciences, University of Arkansas, Fayetteville, AR 72701 and Ralph R. Moldenhauer, Department of Biology, Sam Houston State University, Huntsville, TX 77341.

*PAST AND PRESENT DISTRIBUTIONS OF THE RED-COCKADED WOODPECKER *Picoides borealis* IN THE OUACHITA MOUNTAINS, ARKANSAS.
Joseph C. Neal, Arkansas Cooperative Fish and Wildlife Research Unit, Department of Biological Sciences, University of Arkansas, Fayetteville, AR 72701 and Warren G. Montague, Ouachita National Forest, P.O. Box 100, Waldron, AR 72958.

**ISOLATION OF CA125 USING NEW MONOCLONAL ANTIBODIES.
Lisa A. Lowery, Gary A. Bannon, Hildur, H. Hardardottir, F.C. Miller, J. Gerald Quirk, Jr., and Timothy J. O'Brien, University of Arkansas for Medical Sciences, Departments of Obstetrics and Gynecology and Biochemistry and Molecular Biology, Little Rock, AR 72205 and Laurence M. Raymond, Arkansas Biotechnology Center, University of Arkansas Biomass Research Center, Fayetteville, AR 72701.

*COMPARATIVE QUANTITATIVE STRUCTURE-ACTIVITY ANALYSIS OF CYSTEINE PROTEINASES.
R.I. Sanchez, R.L. Lopez de Compadre, C.M. Compadre, Department of Biopharmaceutical Sciences, University of Arkansas for Medical Sciences, Little Rock, AR 72205, and C. Bhuvaneswaran, Department of Biochemistry, University of Arkansas for Medical Sciences, Little Rock, AR 72205.

**TRIPEPTIDE ANALOGS OF PEPSTATIN: SYNTHESIS & PEPSIN INHIBITION.
Anissa Evans and Rose McConnell, Department of Chemistry, University of Arkansas at Pine Bluff, Pine Bluff, AR 71601.

INHIBITION DATA OF NEW LEUPEPTIN ANALOGS.
Amanda Camp and Rose McConnell, Department of Chemistry,

University of Arkansas at Pine Bluff, Pine Bluff, AR 71601.

*TERNARY CU(II)(3,5-DIPS)2-HUMAN SERUM ALBUMIN COMPLEXES.

Susan T. Shuff, Department of Medicinal Chemistry, College of Pharmacy, University of Arkansas for Medical Sciences, Little Rock, AR 72205, and John R.J. Sorenson, Department of Biology, Henderson State University, Arkadelphia, AR 71923.

*DETERMINATION OF CIMETIDINE IN PHARMACEUTICALS BY CAPILLARY ZONE ELECTOPHORESIS.

Susan Arrowood and A.M. Hoyt, Jr., University of Central Arkansas, Conway, AR 72032.

*IDENTIFICATION OF A GENE INVOLVED IN REGULATING THE STABILITY OF A *Tetrahymena thermophila* SURFACE PROTEIN mRNA.

P.J. McMillan, M.M. Tondravi, Department of Biochemistry and Molecular Biology, University of Arkansas for Medical Sciences, Little Rock, AR 72205; F.P. Doerder, Department of Biology, Washington University, St. Louis, MO 63130; G.A. Bannon, Department of Biology, Cleveland State University, Cleveland, OH44115.

*PHASE ANGLE MEASUREMENT FOR THE EVALUATION OF CUTTING FLUID PERFORMANCE ON A-36 CARBON STEEL DURING COMMON LATHING OPERATIONS.

Gary L. Fuller, Department of Electronics and Instrumentation, University of Arkansas at Little Rock, Little Rock, AR 72204.

**REPRODUCTION IN THE SOUTHERN FLYING SQUIRREL *(Glaucomys volans)* IN THE OUACHITA MOUNTAINS OF CENTRAL ARKANSAS.

Paul T. Caster, Karen D. Stone, Gary A. Heidt and David Saugey, Department of Biology, University of Arkansas at Little Rock, AR 72204 and U.S. Forest Service, Jessieville, AR 71949.

**WINTER HOME RANGE OF FEMALE SOUTHERN FLYING SQUIRRELS *(Glaucomys volans)* IN THE OUACHITA MOUNTAINS OF CENTRAL ARKANSAS.

Karen D. Stone and Gary A. Heidt, Department of Biology, University of Arkansas at Little Rock, Little Rock, AR 72204.

**AGGRESSIVE BEHAVIOR BETWEEN THE TEXAS MOUSE *(Peromyscus attwateri)* AND THE COTTON MOUSE *(P. gossypinus)*.

John A. Peppers, David W. Royal, Gary A. Heidt and Catherine Hall, Department of Biology, University of Arkansas at Little Rock, Little Rock, AR 72204.

BOTANY II/SCIENCE EDUCATION

Chairman: Dr. F.E. Lane, University of Arkansas, Fayetteville

PLANT REGENERATION FROM HERBICIDE RESISTANT RICE *(Oryza sativaL.)* CALLUS.

A.F. Mirlohi, F.H. Huang, L.F. Thompson, R.H. Dilday, and J.M. Al-Khayri, University of Arkansas, Fayetteville, AR 72701.

PHOTOSYNTHETIC EFFICIENCY OF DROUGHT-INDUCED LEAVES IN *Neviusia alabamensis*.

Jennifer Martsolf and Robert Wright, Department of Biology, University of Central Arkansas, Conway, AR 72032.

GROUNDWATER HYDROLOGY OF A POPULATION OF *Lindera melissifolia* IN ARKANSAS.

Dainette Priest and Robert Wright, Department of Biology, University of Central Arkansas, Conway, AR 72032.

PHOTOSYNTHESIS AND WATER RELATIONS OF A RARE SHRUB, *Neviusia alabamensis*.

Robert D. Wright, University of Central Arkansas, Conway, AR 72032.

LEAF COLOR CHANGE IN *Acer saccharum* CORRELATES WITH EARLY OCTOBER TEMPERATURES.

J.L. Wickliff, University of Arkansas, Fayetteville, AR 72701.

ONE TEACHER'S APPROACH TO THE BATTLE AGAINST CHEMOPHOBIA.

Karen C. Weaver, Department of Chemistry, University of Central Arkansas, Conway, AR 72032.

A LABORATORY SKILLS TEST.

Richard S. Mitchell, Arkansas State University, Box 700, State University, AR 72467.

COMPUTERIZED EQUIPMENT AND NETWORKING IN BIOLOGY LABORATORIES: A REPORT ON AN NSF-ILI PROJECT AT UALR.

Alvan A. Karlin, Department of Biology, University of Arkansas at Little Rock, Little Rock, AR 72204.

CRITICAL THINKING WITH BOTANY: USE OF RAPID CYCLING *Brassica* (RCBr), WISCONSIN "FAST PLANTS".

James H. Peck, Department of Biology, University of Arkansas at Little Rock, Little Rock, AR 72204.

AQUATICS/INVERTEBRATES

Chairman: Dr. L. Rusert-Kraemer, University of Arkansas, Fayetteville

EVIDENCE OF SIGNIFICANT GENETIC VARIATION IN THE NON-TRANSFORMING SALAMANDER GENUS *Amphiuma*.

Alvan A. Karlin, Department of Biology, University of Arkansas at Little Rock, Little Rock, AR 72204 and D. Bruce Means, 1313 North Duval St., Tallahassee, FL32303.

Aeromonas hydrophilia ASSOCIATED WITH DEATH IN AN ARKANSAS ALLIGATOR.

James J. Daly, Department of Microbiology and Immunology, University of Arkansas for Medical Sciences, Little Rock, AR 72205; Samuel Barkley, Arkansas Game and Fish Commission, Little Rock, AR; and Peggy Benton, St. Vincent's Infirmary Medical Center, Clinical Laboratory, Little Rock, AR.

THE IMPORTANCE OF REGIONAL COLLECTIONS IN BIOGEOGRAPHIC STUDIES: AN EXAMPLE FROM THE CADDISFLIES (INSECTA: TRICHOPTERA).

David E. Bowles, Captain, U.S. Army, Medical Corp, San Antonio, TXand Robert T. Allen, Department of Entomology, University of Arkansas, Fayetteville, AR 72701.

FIRST REPORT OF THE SUBGENUS *Podocampa* (INSECTA: DIPLURA: CAMPODEIDAE: *Campodea*) NORTH OF MEXICO: *Campodea (Podocampa) snowi*, A NEW SPECIES FROM ARKANSAS.

Robert T. Allen, Department of Entomology, University of Arkansas, Fayetteville, AR 72701.

SPIDERS COLLECTED IN SOUTHEAST ARKANSAS BY THE PIT TRAP METHOD.

Peggy Rae Dorris, Henderson State University, Arkadelphia, AR 71923.

THE HABITAT VALUE OF AQUATIC PLANTS: EFFECTS OF *Potamogeton nodosus* ON INVERTEBRATES IN THE SALINE RIVER, BRADLEY COUNTY, ARKANSAS.

Edmond J. Bacon, Department of Natural Sciences, University of Arkansas, Monticello, AR 71655 and Andrew C. Miller, US Army

Engineer Waterway Experiment Station, Vicksburg, MS 39180.

AN ANNOTATED LIST OF THE LEPIDOPTERA KNOWN FROM MAGAZINE MOUNTAIN, ARKANSAS.
Richard Brown, Mississippi State University, Starkville, MS and Robert T. Allen, Department of Entomology, University of Arkansas, Fayetteville, AR 72701.

BEHAVIORAL DEACTIVATION OF PLANT DEFENSES BY INSECT HERBIVORES.
David E. Dussourd, Department of Biology, University of Central Arkansas, Conway, AR 72032.

BIOCHROME TESTING TO DETERMINE EUTROPHICATION LEVELS OR STAGES.
Samuel J. Gates and John D. Rickett, Department of Biology, University of Arkansas at Little Rock, Little Rock, AR 72204.

RELATIONSHIP OF TEST HOLE DEPTH AND SOIL PROPERTIES ON PERCOLATION RATES FOR TWO SOILS IN ARKANSAS.
Paul B. Francis, University of Arkansas at Monticello, Monticello, AR 71655.

CHEMISTRY/ENGINEERING II

Chairman: Dr. D.J. Davis, University of Arkansas, Fayetteville

PREPARATION OF A SERIES OF SUBSTITUTED N-PHENYL 5-BROMO-2-CHLORO AND 5-BROMO-6-CHLORONICOTINATES OF POTENTIAL AGRICULTURAL INTEREST.
Frank L. Setliff, Maximillia M. Muguluma and Jody Z. Caldwell, Department of Chemistry, University of Arkansas at Little Rock, Little Rock, AR 72204.

AN X-RAY FLOURESCENCE LAB FOR ADVANCED ANALYTICAL STUDENTS.
Michael W. Rapp and William S. Taylor, Department of Chemistry, University of Central Arkansas, Conway, AR 72032.

PROPYLENE GLYCOL ALTERS ACETAMINOPHEN TOXICITY IN MICE.
T.A. McRae, J.E. Snawder, A.R. Warbritton and D.W. Roberts, National Center for Toxicological Research, Jefferson, AR 72079.

STRUCTURE-ACTIVITY RELATIONSHIPS OF PHOTOTOXIC THIOPHENES.
R.L. Compadre and C.M. Compadre, College of Pharmacy, University of Arkansas for Medical Sciences, Little Rock, AR 72202; R.J. Marles and J.T. Arnason, University of Ottawa, Ottawa, Ontario, Canada KIN6N5.

THE ELECTROCHEMICAL CHARACTERIZATION OF M1.
Latriana Hairston, Kimberly Harris, Ricky Bean and B.T. Duhart, Department of Chemistry, University of Arkansas at Pine Bluff, Pine Bluff, AR 71601.

DETERMINATION OF STREPTOMYCIN IN INJECTABLE PREPARATIONS BY GAS-LIQUID CHROMATOGRAPHY.
A.M. Hoyt, Jr., Susan Arrowood, Joachin Jessup and Mark Woods, University of Central Arkansas, Conway, AR 72032.

CONFORMATIONAL HETEROGENEITY IN A LINEAR PENTAPEPTIDE.
S. Ramaprasad, Departments of Radiology and Pathology, University of Arkansas for Medical Sciences, Little Rock, AR 72205.

INSTRUMENTATION FOR A POSTURAL SWAY PLATFORM.
Robert B. Shanks and Paul McLeod, Department of Electronics and Instrumentation, University of Arkansas at Little Rock, Little Rock, AR 72204.

A SIMPLE SYNCHRONOUS DETECTOR FOR SPECTROSCOPY STUDIES.
Mokhtar Mofidi and M. Keith Hudson, Department of Electronics and Instrumentation, University of Arkansas at Little Rock, Little Rock, AR 72204.

INVESTIGATION OF INFRARED EMISSIONS FROM FLAMES AND ROCKET PLUMES USING A RADIOMETER.
Kathy Underhill, M. Keith Hudson, Jason Willis, Department of Electronics and Instrumentation, University of Arkansas at Little Rock, Little Rock, AR 72204 and Matt Russo, Hercules Aerospace, 1101 Johnson Avenue, McGregor, TX 76657.

CHROMATOGRAPHIC DATA ACQUISITION AND PEAK DETECTION SOFTWARE.
William G. Hood and M. Keith Hudson, Department of Electronics and Instrumentation, University of Arkansas at Little Rock, Little Rock, AR 72204.

EVALUATION OF PARTICULATE AIR FILTERS FOR INDOOR AIR CLEANING.
M.R. Clark, K.B. Tennal, T.W. Rimmer and M.K. Mazumder, Department of Electronics and Instrumentation, University of Arkansas at Little Rock, Little Rock, AR 72204.

PREPARATION OF A SERIES OF N-PHENYLAMIDES OF 5-BROMO-6-CHLORONICOTINIC ACID AND 5-BROMO-2-CHLORONICOTINIC ACID.
Jody Z. Caldwell and Frank L. Setliff, Department of Chemistry, University of Arkansas at Little Rock, Little Rock, AR 72204.

VERTEBRATES/GEOLOGY

Chairman: Dr. T. Martin, University of Arkansas, Fayetteville

LANDOWNER REPORTS OF DEER HUNTER DAMAGE IN ARKANSAS.
Richard A. Kluender and T. Bently Wigley, Jr., Forest Resources Department, University of Arkansas at Monticello, Monticello, AR 71655.

DISTRIBUTION, SCUTELLATION, AND REPRODUCTION IN THE QUEEN SNAKE, *Regina septemvittata* (SERPENTES: COLUBRIDAE), FROM ARKANSAS.
Stanley E. Trauth, Department of Biological Sciences, Arkansas State University, State University, AR 72467.

POSTERIOR MAXILLARY FANGS OF THE FLATHEAD SNAKE, *Tantilla gracilis* (SERPENTES: COLUBRIDAE), USING SCANNING ELECTRON MICROSCOPY.
Stanley E. Trauth, Department of Biological Sciences, Arkansas State University, State University, AR 72467.

HABITAT UTILIZATION AND DISTRIBUTION OF THE FOURTOED SALAMANDER, *Hemidactylium scutatum*, IN THE OUACHITA MOUNTAINS.
David A. Saugey, United States Forest Service, Jessieville, AR 71949 and Stanley E. Trauth, Department of Biology, Arkansas State University, State University, AR 72467.

RANGE EXTENSION OF THE ENDANGERED GRAY BAT, *Myotis grisescens*, INTO THE ARKANSAS RIVER VALLEY.
Thomas A. Nelson, David A. Saugey, and Lee E. Carolan, Fish and Wildlife Biology Program, Arkansas Tech University, Russellville, AR 72801 and United States Forest Service, Jessieville, AR 71949.

IDENTIFYING *Colibri* HUMMINGBIRDS IN ARKANSAS USING INDIRECT MEASUREMENTS.
Douglas A. James, Department of Biological Sciences, University of Arkansas, Fayetteville, AR 72701.

ORGANOCHLORINE PESTICIDE CONCENTRATIONS IN VARIOUS SPECIES OF SOUTHBOUND MIGRATORY PASSERINES IN NORTHEASTERN LOUISIANA.

Ragupathy Kannan, Department of Biological Sciences, University of Arkansas, Fayetteville, AR 72701 and David T. Kee, Department of Biology, Northeast Louisiana University, Monroe, LA 71209.

REPRODUCTIVE BIOLOGY OF FEMALE WHITE-TAILED DEER ON HOLLA BEND REFUGE.

Thomas A. Nelson, Arkansas Tech University, Russellville, AR 72801.

HYBRIDIZATION AND SYSTEMATICS IN MONOGAMOUS VERTEBRATES: THE GENUS *Canis* IN ARKANSAS.

Raymond Pierotti, Alicia Shirakbari and David Pennock, Department of Biological Sciences, University of Arkansas, Fayetteville, AR 72701.

OBSERVATIONS ON E NATURAL HISTORY OF THE MEDITERRANEAN GECKO *Hemidactylus turcicus* (SAURIA: GEKKONIDAE) IN NORTHWESTERN ARKANSAS.

Mark A. Paulissen, Department of Biology, Slippery Rock University, SlipperyRock, PA 16507 and Thomas M. Buchanan, Division of Science, Math and Engineering, Westark Community College, Ft. Smith, AR 72913.

REPORTED ANIMAL RABIES IN ARKANSAS: 1981-1990. A TEN YEAR UPDATE.

Laura R. Chandler, Karen D. Stone, Gary A. Heidt, Department of Biology, University of Arkansas at Little Rock, Little Rock, AR 72204 and David A. Saugey, U.S. Forest Service, Jessieville, AR 71949.

PLEISTOCENE MAMMALS FROM THE SOUTH SULPHUR RIVER, HUNT COUNTY, TEXAS.

Leo Carson Davis, Department of Physical Sciences, Southern Arkansas University, Magnolia, AR 71753 and Kenneth M. Ball, Barton Junior High School, 400 West Faulkner, El Dorado, AR 71730.

EFFECTIVENESS OF VARPEL ROPE(TM) ON WILD RAT *(Rattus norvegicus)* AND MICE *(Mus musculus)* IN LABORATORY AND FIELD CONDITIONS.

J.D. Wilhide, M.D. Fletcher and V.R. McDaniel, Department of Biological Sciences, Arkansas State University, State University, AR 72467.

OBSERVATIONS ON A RESIDENT POPULATION OF *Myotis lucifugus*, IN JACKSON COUNTY, ARKANSAS.

M.D. Fletcher and J.D. Wilhide, Department of Biological Sciences, Arkansas State University, State University, AR 72467.

THE BIOTA OF MAGAZINE MOUNTAIN (I): AN OUTLINE OF THE NATURAL HISTORY OF MAGAZINE MOUNTAIN

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ABSTRACT

One plant and five invertebrate species are thought to be endemic to Magazine Mountain, Logan County, Arkansas. The mountain is the highest point in the Interior Highlands reaching 2,753 feet. Previous studies have recorded over 650 species of plants including (or in addition to) 27 fern species. The animal fauna is less well known. It is suggested that an inventory of the biota of the mountain could be completed within the foreseeable future. It is further suggested that such an inventory would be useful in answering questions relevant to understanding the evolution and biogeography of selected taxa in North America. A list of collecting localities and approximate locations are given.

INTRODUCTION

Data concerning the total special composition (both plants and animals) of terrestrial communities in North America are almost non-existent in the published literature. One of the few efforts to study the entire biota of a limited geographical area was a biological survey of Mount Desert Island, Maine (Proctor, 1946). Rather than comprehensive surveys of biotas, one is more likely to find floral or faunal works or checklists on particular taxa available for specific taxa. Such floral and faunal works and checklists are certainly useful but they beg the question: "How many species of plants and animals are present in a particular area?" We are, for the most part, left without an answer to this question.

Comprehensive biological surveys, even for small geographical areas, are difficult to conduct. Sailer (1969) discussed some of the problems associated with such surveys. Among these problems are the lack of specialists to identify the specimens, obtaining funding, a long term commitment to the project, and the organization and storage of collections until they can be processed and identified. However, if these problems and others can be at least partially resolved, the benefits to biology, evolutionary biology in particular, could be enormous. For example, once the species composition of an area is known (perhaps known at the 75% level of completion), answers to questions relevant to an understanding of the relationship between evolution and ecology become possible. Indeed, we may be able to study whole organism evolution, biology, and species interactions more precisely than has been possible to date.

For a terrestrial community such as a deciduous forest in eastern North America, it is difficult to even estimate the number of animal species that might be present. Peck (1989) has discussed this problem in relation to a faunistic study he is doing on the insects of the Florida Keys. Using what data are available he estimated "a total of some 5,000 insect species, but this seems conservative because over 6,000 insect species are claimed for Mount Desert Island, Maine, USA (Proctor 1946)." Peck (personal communication) said that the Florida Keys are a somewhat depauparate biota, i.e. the biota is not too diverse. In contrast to Peck's estimate, Karl Stephan (personal communication), working in a more diverse area, has collected over 3,700 species of beetles (Insecta: Coleoptera) in Latimer County, Oklahoma over a 15 year period. Latimer County is on the western edge of the decidious forest in the Ouachita Mountains. Based on the limited data available one might estimate that the number of arthropod species (spiders, mites, centipedes, millipedes, insects, etc.) found in a "typical" eastern decidious forest community may exceed 20,000 to 30,000 species. This estimate does not include the many other non-arthropod invertebrate taxa, plants, fungi, vertebrates, etc. The question that immediately arises is "Can an inventory of the biota of an area be completed in a realistic period of time?"

The answer I offer to the question just posed is a qualified yes. Although one may strive to do a complete inventory of an area, one must also accept the fact that the level of completeness of identification would be uneven in the taxa occurring in the area. However, I would argue that although a biotic inventory may never be "complete," this should not deter workers from engaging in such studies. I point out that the astronomers have been estimating the number of celestial bodies and the amount of matter occurring in the universe for decades, revising their estimates upwards and/or downwards each year. But more importantly, I would reiterate the suggestion that biological inventories, at any level of completeness, will open many new avenues of investigation and will generate a number of different questions, perhaps even new questions that have to be answered if we are to understand our environment and the processes by which the organisms in that environment have evolved.

In the process of inventorying biotas I would suggest that biologists can also investigate important scientific questions. Suppose, for example, that the area to be studied is known to have one or more local endemic species and also species with disjunct populations. Two questions might be: (1) What is the percentage of endemism in the local area in relation to the number of non-endemic taxa in the same genus or higher taxon? and (2) Why does one genus exhibit local endemic forms while other genera have only disjunct populations? Perhaps a third question, following from question two, might be: Have different taxa been isolated for varying lengths of time? It might be possible to answer, at least in part, these types of questions as one proceeds with a basic inventory of an area. When questions such as the ones just suggested are considered, the value of biological inventories is greatly enhanced.

This paper is the first in a series that will report the results of a biological inventory of a local, somewhat isolated area in the Interior Highlands of North America, Magazine Mountain, Logan County, Arkansas. A number of papers and unpublished reports have previously documented a small portion of the Magazine Mountain biota. Building on the information now available and work done on the mountain during the past six years, it will be possible to inventory a significant part of the mountain's biota within the forseeable future. Hopefully, the publication of the inventory data as quickly as possible will encourage specialists in a number of diverse fields to lend their expertise to this work.

LOCATION

Magazine Mountain is located in Western Arkansas in southeastern Logan County, Arkansas, south of the town of Paris. The mountain is

[1]Published with the approval of the Director, Arkansas Agricultural Experiment Station, University of Arkansas, Fayetteville, AR 72701.

approximately 55 miles southeast of Ft. Smith, Arkansas, and 100 miles northwest of Little Rock, Arkansas. Access is via State Highway 309 from either Paris to the north, or Havana to the south. The mountain rises about 2,400 feet above the level of the Arkansas River which is 16 miles to the north, to an elevation of 2,753 feet above sea level. The mountain lies along the south edge of the Arkansas River Valley.

GEOLOGY

The bedrock of Magazine Mountain is Pennsylvanian sedimentary rock consisting (from the top down) of the Savannah Sandstone Formation (about 800 feet thick), the McAlester Shale Formation (about 700 feet thick), the Hartshorne Formation (about 220-223 feet thick), all of the Des Moines Series, and the Atoka Series which consists entirely of the Atoka formation (about 10,000 feet thick) (Anonymous, 1960).

The mountains lying within the area known as the Arkhoma Basin (Magazine Mountain, Mt. Nebo, and Petit Jean Mountain among others) are the results of erosional processes. The Arkhoma Basin was once an uplift area lying between the northern Ozark uplift and the southern Ouachita Mountains. As erosion proceeded in the Arkhoma area, a number of tall mountains were left in stark contrast to the surrounding landscape. The Arkansas River is now a prominent feature of the Arkhoma Basin and flows through Arkansas and part of eastern Oklahoma. The age of the Arkansas River is unknown, and therefore, the contribution this river has made to the erosion of the Arkhoma Basin is uncertain. It has been postulated that the precursor of the present day river was a vast drainage area receiving run-off from the northern Ozark and southern Ouachita Mountains. This drainage basin may have served as an effective barrier for the dispersal of some organisms (Carlton & Cox, 1990).

CLIMATE

The climate of the Magazine Mountain area was discussed in a U.S. Department of Agriculture Environmental Impact Statement compiled by an anonymous source (Anonymous, 1960).

"The average annual temperature on the summit of Magazine Mountain is 57°F, 6° cooler than the average of 63°F at its base and the surrounding areas. During January the average summit temperature is 37°F while that of the base and surrounding areas is about 42°F. The July summit temperature averages 76°F while that of surrounding areas average 82°F. The midsummer summit temperature is frequently 10-25 degrees cooler than that of the surrounding valleys. Temperatures on the mountain ranged from a high of 103°F to a low of 7°F during the period 1951-1960.

> "Precipitation in the area is usually abundant and well distributed throughout the year with an average of 92 days per year having measurable precipitation. The average annual precipitation of 55 inches on the summit decreases to about 50 inches at lower elevations. Precipitation ranged from a high of 81 inches to a low of 37 inches during the period 1951-1960.
>
> "The area has heavy fog on the average of 8.3 days per month. November, with an average of 16 foggy days and February, with an average of 14 foggy days, have the highest occurrences. March and April have the lowest occurrences. Because of the mountainous terrain, fog is frequently localized. At times heavy fog covers lower elevations while the summit remains fog free."

VEGETATION

Three major reports have described and cataloged the vegetation of Magazine Mountain. Pyle (1939) studied the plants found on Magazine Mountain and listed some 434 species. Moore (1926) published a short paper listing 27 fern species and discussed the fern communities found in some of the moist protected habitats. Tucker (1972), after an extensive study of the vegetation on the mountain, listed over 600 species of plants that he had collected, or that he had confirmed as being present by the existence of herbarium specimens.

Tucker (1972) suggested that the vegetation on Magazine Mountain could be divided into three main units with subunits under two of the main divisions. These divisions are quite useful in understanding some of the major habitats on the mountain. Tucker's (1972) divisions and discussion of each of the major habitats, sometimes verbatim, were as follows:

I. PLATEAU SURFACE

Because the top of the mountain (the central part of the plateau) was once inhabited and developed, little of the original vegetation remains. However, the areas near the rim were not suited for farming and were left undisturbed.

I. A. Southern Rim of Plateau. Along the south rim is a mosaic of stunted, gnarled trees and open areas. The trees are mostly Red Cedar *(Juniperus virginiana)*, Blackjack *(Quercus marilandica)* and Post Oak *(Q. stellata)*, Gum Bumelia *(Bumelia lanuginosa)*, Fringe Tree *(Chinoanthus virginica)*, and Farkleberry *(Vaccinium arboreum)*. The more open areas may be composed of bare or lose rock. Other open areas are covered with Big Bluestem *(Andropogon gerardii)*, Jointgrass, Panic Grass (*Panicum* spp.), Gamma Grass *(Tripsacum dactyloides)*, Love Grass (*Erogrostis* spp.), Black-eyed Susan *(Rudbeckia grandiflora)*, Thistle (*Cirsium* spp.), Blazin Star (*Liatris* spp.), and Aster (*Aster* spp.).

The most important features along the south rim are the "spring seeps" present at the onset of spring rains and snow melt. These seeps provide microhabitats for amphipods and other freshwater invertebrates.

I. B. Northern Rim of Plateau. The north rim of the plateau is more moist than the southern rim, and there are more ravines of larger size. The tree assemblage is somewhat different, consisting of Northern Red Oak *(Quercus rubra* var. *borealis)*, White Oak *(Q. alba)*, and Chinkapin Oak *(Q. muhlenbergi)*; several species of Hickory (*Carya* spp.); Basswood *(Tilia americana)*; Serviceberry *(Amelancher arboreta)*; and Sugar Maple *(Acer saccharum)*. The rare Prickley Gooseberry *(Ribes cynosbati)* occurs along the rim at Brown Springs. The north rim is notable because it is the only known locality for the diminutive Maple-leaved Oak *(Q. shumardii* var. *acerifolia)*.

I. C. Sphagnum Bog. There are several low areas toward the west end of the mountain that support assemblages of several species of Peat Moss (*Sphagnum* spp.). The spring-fed seep at Dripping Springs is the largest and most accessible. The Small-headed Pipewort *(Eriocaulon kornickianum)* is present, along with the occasional occurrence of Ragged Fringed Orchid *(Habenaria lacera)*, Yellow Fringed Orchid *(Habenaria cilliaris)*, Green Adder's Mouth *(Malaxis unifolia)*, and Quillwort *(Isoetes melanopoda)*. Each of these seep plants is considered rare in Arkansas.

I. D. Disturbed areas. When Tucker discussed the disturbed areas in 1972 he noted these areas were "still noticeable but are rapidly disappearing as the natural vegetation re-establishes itself." At the present time (1991) the older home sites, flower gardens, etc. have become obscure and are often difficult to locate. The area around the old lodge site on the south slope is still evident.

II. SLOPES

II. A. North and East Slopes. The North-facing slope of the mountain supports a rich and diverse flora. The largest tree dominants are White Oak *(Q. alba)*, Red Oak*(Q. falcata)*, Black Oak *(Q. velutina)*, Ohio Buckeye *(Aesculus glabra)*, Black Gum *(Nyssa sylvatica)*, and often Ozark Chinkapin *(Castanea pumila* var. *ozarkensis)*. In the steeper and

more inaccessible ravines, there are very large specimens of most of these species. The more common shrubs are Prickly Gooseberry *(Ribes synosbati)*, Spicebush *(Lindera benzoin)*, and Bladdernut (*Staphylea* sp.). A few specimens of the relatively rare Yellow-Wood *(Cladrastis lutea)* may also be found. Ground cover may consist of dense patches of Dutchman's Breeches *(Dicentra cucullaria)*, Bellwort *(Uvularia grandiflora)*, Trillium (*Trillium* spp.), Spiderwort *(Tradescantia ernestiana, T. ohiensis*, and *T. ozarkana)*, Toothwort *(Dentaria laciniata)*, and Mayapple *(Podophyllum peltatum)*. A few deep ravines on the east slope, especially Bear Hollow, are almost identical in plant species composition to those on the north slope.

II. B. South and West Slopes. The south slope and part of the west-facing slope support a Shortleaf Pine *(Pinus echinata)* and deciduous tree forest. Some areas are predominately pine. The deciduous trees may be White Oak *(Q. alba)*, Post Oak *(Q. stellata)*, Black Oak *(Q. velutina)*, and a number of Hickory species (*Carya* spp.). Understory trees may include Flowering Dogwood *(Cornus florida)*, Hawthorn (*Crateaqus* spp.), Redbud *(Cercis canadensis)*, and Sassafras *(Sassafras albidum)*.

III. ROCK OUTCROPS

Concerning the rock outcrops, Tucker (1972) gave the following analysis: "The rock outcrops of the shaded and protected northern and eastern slopes are particularly noteworthy for their pockets of ferns of numerous species. The shaded outcrop in the vicinity of Dripping Springs is very rich in fern diversity. The very rare Hay-scented Fern (*Dennctaedia punctilobula* [Michx.] Moore), and Rocky Mountain Spleenwort (*Woodsia scopulina* [D. C. Eat.] var. *appalachiana* [T. M. C. Taylor] Morton) are among the more interesting of that region. Also growing abundantly here is a grass common in the mountains of the Appalachian region, Hairgrass *(Descampsia flexuosa)*." Some of the outcrops on the plateau (and northern slopes) support communities of the relatively rare Indigo Bush *(Amorpha ouachitensis)* also known as the Ouachita Leadplant. Peck (1986) reported the prescence of the Spinulose Wood Fern (*Dryopteris carthusiana* H. B. Fuchs) on the north slope at Brown's Spring. The only other locality of this plant in Arkansas is from Stone County, approximately 70 miles northeast of Magazine Mountain. This is a predominately northern species and the Magazine Mountain population represents a distinct disjunction.

FAUNA

The early work on the fauna of Magazine Mountain, 1900-1985, was sporadic and consisted of the description of new taxa. The following species were described from various localities on the mountain and are still known only from Magazine Mountain: *Mesodon magazinensis* Pilsbry & Farris (1906); *Paravitrea aulocogyra* Pilsbry & Farris (1906); *Stygobromus elatus* Holsinger (1967); *Arianops sandersoni* Barr (1974). The first two organisms are land snails, the third is a fresh water amphipod, and the fourth is a short-winged mold beetle. *Mesodon magazinensis* has been placed on the federal list of threatened and endangered species.

During the past six years an additional two new insect species and one genus have been found on Magazine Mountain and are thought to be endemics. The new endemic taxa are as follows: a jumping bristletail *Pedetontus gerschneri* Allen (1992) (in press); a caddisfly *Paucicalcaria ozarkensis* Mathis & Bowles (1989) (an endemic genus and species). Other species that were originally found on the mountain but have subsequently been found in other areas in the Interior Highlands are as follows: a mayfly *Paraleptophlebia calcarica* Robotham & Allen (1988); a lace bug *Acalypta susanae* Allen *et. al.* (1988); a ground beetle *Scaphinotus parisana* Allen & Carlton (1988); a new genus and species of short-winged mold beetle *Ouachitychus parvoculus* Chandler (1988).

In addition to the new insect species that have been discovered on the mountain, Tedder and Allen (1989) listed 68 species of Collembola collected during a three year study.

No recent inventories of the vertebrate fauna of Magazine Mountain have been published. Baerg (1927) listed 48 bird species as summer residents on the mountain.

SPECIFIC LOCALITIES AND METHODS

Since 1985, the inventory of the biota of Magazine Mountain has concentrated on the arthropods. Although any area on the mountain is subject to study, collecting has been concentrated at several specific localities. Figure 1 is a schematic diagram showing distances from major intersections to localities from which numerous samples have been taken. The following is a list of these localities:

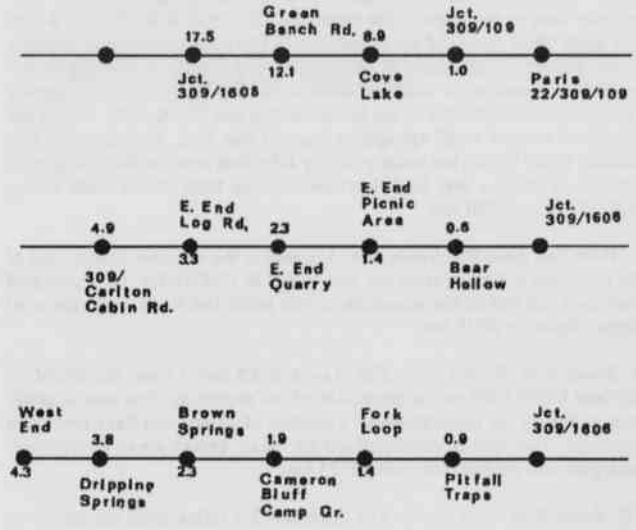

Figure 1. Distances, in miles, of primary collecting from major highway/road intersections.

1. *Cove Lake*. Located near the base of the mountain approximately 8.9 miles south of Paris on Highway 309. The campground has been used as a base of operation. The area has a greater concentration of pines and is similar to the upper reaches of the east side and south slope of the mountain. Elevation 1050 feet.

2. *Gutter Rock Creek*. This stream emanates from a number of run-off areas on the north slope of the mountain including Brown Springs. The principle collecting area has been at the low water bridge crossing on Green Bench Road, approximately 2.5 miles west of the junction of Highway 309 and Green Bench Road. Elevation 1300 feet.

3. *Slocum Springs*. Located on the north slope, the spring is reached by traveling west on Green Bench Road 4.7 miles from Highway 309. A small, overgrown, abandoned road on the south side of Green Bench Road leads through a clear cut area, then into the north slope forest. It is about a two mile hike up the north slope to Slocum Springs. The spring itself is small and difficult to locate. Elevation 2050 feet.

All the remaining localities are on the upper reaches of the mountain. Each locality is measured in miles from the intersection of Highway 309 and U.S. Forest Road (USFR) 1606. The Forest Road extends west on the main portion of the plateau of Magazine Mountain. Greenfield Picnic Area is located at the intersection.

4. *Cameron Bluff Campground.* This area has been used as a base of operation on most collecting trips since 1989. The area is 1.9 miles west of Intersection of 309 and USFR1606. Elevation 2500 feet.

5. *Signal Hill.* The north entrance to the Signal Hill Trail begins across the road from the entrance to the Cameron Bluff Campground. Collecting has been at numerous points along this trail. The trail leads up Signal Hill to the highest point on the mountain, 2753 feet.

6. *Brown Springs Picnic Area.* Located 2.3 miles west of Inters. of 309 and USFR1606. The spring is free flowing in the spring but usually dry by mid June. This area is one of the major localities of the endemic Maple-leaved Oak. Elevation 2575 feet.

7. *Dripping Springs.* Located 3.8 miles west of Inters. of 309 and USFR 1606. Just beyond the entrance to Brown Springs, a dirt/gravel road extends west to the edge of the mountain. The road is marked by a sign that reads "Fire Tower" /"Electronic Site". The spring must be reached by hiking about 0.5 mile along an abandoned road. This road is easily recognized by several large boulders used to deter vehicle traffic. Dripping Springs is 3.8 miles west of the Inters. of 309 and USFR 1606. This is the largest of several small sphagnum bogs in this area. The spring is free flowing in the spring but usually dry by July. Just north of the spring are a number of ravines that lead downward to the base of the north facing cliff. Elevation 2650 feet.

8. *West End Area/Electronic Site.* Located at the extreme western end of the mountain 4.3 miles from the Inters. 309 & USFR1606. An abandoned road near the end of the mountain on the south rim leads down the west slope. Elevation 2675 feet.

9. *South Rim, West Cabin Site.* Located 2.5 miles from the Inters. of 309 and USFR1606 on the south side of the mountain. This area is easily recognized by the foundations of a number of cabins that have now been removed. The area is characterized by clear, grassy areas interspersed with pine and juniper. Elevation 2575 feet.

10. *South Rim, East Cabin Site.* Located 2.9 miles from the Inters. of 309 and USFR 2606. Similar to the West Cabin Site but with more open grassy areas along the south rim. Elevation 2550 feet.

11. *Mossback Ridge.* This is the crest that extends along the eastern part of the mountain. The north and south slopes of the ridge appear to be very different in terms of moisture retention especially in late July, August, and September. The north slope is noticeably more moist than the south slope, even though the two sides are separated by only a short distance. One of the sites used most frequently is 0.9 mile west of the Inters. of 309 and USFR 1606. Elevation 2550 feet.

12. *Bear Hollow.* Located 0.6 mile south of Inters. of 309 and USFR 1606 on the east side of Highway 309. This hollow contains a rich, older vegetational component as evidenced by the diameter of many of the large trees in the hollow. Elevation 2400 feet.

13. *East End Picnic Area.* Located 1.4 miles south of Inters. of 309 and USFR 1606. The immediate area around the picnic tables is predominately young pine and small hardwoods. The area supports a wide variety of wildflowers early in the spring. Elevation 2400 feet.

14. *East End Pond.* Almost directly across the road from the entrance to the East End Picnic Area is an overgrown dirt road leading to a small man-made pond. Location of the road entrance is 1.4 miles south of the Inters. of Highway 309 and USFR 1606. Elevation 2400 feet.

15. *East End Quarry.* Located 2.3 miles south of the Inters. of Highway 309 and USFR 1606 on the east side of Highway 309. The quarry area was created in the early 1970s when Highway 309 was renovated and paved. The quarry pit contains water throughout the year. A large clear cut area borders the pit on the north side. Elevation 2250 feet.

16. *East End Log Road.* Located 3.3 miles south of the Inters. of Highway 309 and USFR 1606 on the west side of Highway 309. This abandoned road extends west along the south slope of the mountain. Within the first one-half mile of the road there are a number of spring run-off streams that are usually dry by mid July. Elevation 1990 feet (bench mark reading).

17. *Junction, 309/Carlton Cabin Road.* Located 4.9 miles south of the Inters. of Highway 309 and USFR 1606. The area is predominately pine with some mixed hardwoods. Elevation 1370 feet.

DISCUSSION

Published reports and the preliminary data that have been collected during the past six years demonstrate that Magazine Mountain harbors a large and diverse flora and fauna. A significant number of species appear to be very restricted local endemics while other species are disjunct populations of species with more extensive ranges in northeastern North America and perhaps in western North America.

It is possible that an inventory of the biota of Magazine Mountain could be completed within the forseeable future. Such an inventory would form the foundation for other inventory studies throughout the Interior Highlands and in other parts of North America. The inventory would also lead to a better understanding of the biogeography of selected taxa and the concept of endemism. Workers interested in participating in this study are encouraged to contact the author.

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THE BIOTA OF MAGAZINE MOUNTAIN (II): A PRELIMINARY LIST OF THE MACROLEPIDOPTERA FAUNA

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ABSTRACT

Collections during the past three years have demonstrated a large and diverse Lepidoptera fauna on Magazine Mountain, Logan County, Arkansas. During the study, over 5,000 specimens were collected at ten different localities on the mountain. To date, 274 species of macromoths have been identified. Twenty-six of these species are new state records while four of the taxa appear to be new species. Localities and the approximate dates when the specimens were collected are reported.

INTRODUCTION

The Lepidoptera species of an area constitute a significant part of the overall fauna. Adults are important pollinators, whereas the larvae feed on a variety of plants and are an important food source for other insect species and vertebrates, particularly birds. From the preliminary data, the Lepidoptera fauna of Magazine Mountain appears certainly large and diverse. Over 5,000 specimens have been collected and partially identified. This paper reports on the macromoth segment of the fauna of Magazine Mountain. The term macrolepidoptera has been used for more than a century to distinguish the families that include the large butterflies, skippers, and moths from the microlepidoptera, which includes families of mostly smaller moths. The macrolepidoptera is not a natural group, because butterflies and skippers are considered to be more closely related to moths assigned to microlepidoptera than to moths assigned to macrolepidoptera (Zimmerman, 1978). This paper lists only the moths that have traditionally been assigned to the macrolepidoptera. We have used the designation "macrolepidoptera" in order to be specific.

Numerous lists of species of macromoths and other Lepidoptera have been made for specific areas in North America during recent years. Among lists for the eastern section of United States, Tietz (1951) reported 1,049 species of macromoths occurring in Pennsylvania.

Blanchard *et al.* (1985), reported 453 species of macrolepidoptera (excluding butterflies and skippers) from Welder Wildlife Refuge, which occupies 7,800 acres in the transition zone between the prairies and plains of south Texas. Their list was based on approximately 23 years of collecting by numerous individuals. Rings and Metzner (1989) reported 417 species of macrolepidoptera moths in a three year survey at the Mohican State Forest and Mohican State Park in Ashland County, Ohio. Profant (1990, 1991) reported 318 species of macromoths from survey of the Sand Pine Scrub area of Blue Spring State Park in Volusia County, Florida, and he listed 459 species occurring on Beaver Island Archipelago in Lake Michigan.

The present study reports 274 species of macromoths collected during three years of sampling at ten sites on Magazine Mountain. Twenty-six of these species are new state records. Four of the taxa collected appear to represent new species and have been tentatively assigned to the following genera: *Cirrhophanus*, *Leuconycta*, *Protoperigea*, and *Zanclognatha*. The junior author estimates that over 1,500 species of Lepidoptera may eventually be recorded from Magazine Mountain.

METHODS

With the exception of one species of *Cirrhophanus*, all specimens were collected with an ultraviolet blacklight, either at a sheet suspended in front of the light or in a box trap. The method for collecting and preparing specimens has been described by Hodges, as quoted by Zimmerman (1978). The *Cirrhophanus* species was collected by sweeping flowers of *Bidens*. During the first three years of this study (1988, 1989, 1990), specimens have been collected on approximately 55 nights. This paper is based on the identification of approximately 3,000 specimens of the 5,000 plus specimens that have been collected.

Nomenclature follows Hodges *et al.* (1983). New state records were based on ranges reported by Covell (1984) for moths in eastern North America. Species that have tentatively been identified as possibly new and undescribed were examined by Tim McCabe of the New York State Museum, Albany.

The following is a list of macrolepidoptera collected at Mt. Magazine, Arkansas; numbered localities listed in Table 1; months (M=May, Jn=June, Jy=July, A=August) are divided into first half (1=days 1-15) and second half (2=days 16-30/31); entry of month without number indicates collections made throughout month. Asterisk indicates new state records.

Table 1. Localities of collections at Mt. Magazine, Arkansas. Elevations in ( ) are those used by the junior author.

1. 1050' (1020'), Cove Lake Campground, T7N,R25W, sec 35SE
2. 2550' (2540-2560'), T6N,R25W, sec 22N, Cameron Bluff Campground.
3. 2753' (2600-2640'), T6N,R25W, sec 22N, Signal Hill
4. 2575' (2600'), S. Rim, W. Cabin Site, T6N,R25W, sec 22SW
5. 2650' (2640'), Dripping Springs Rd., T6N,R25W, sec 20SE
6. 2550' (2680-2700'), Mossback Ridge, T6N,R25W, sec 23SW
7. 1300' (1350'), Wicked Creed Rd., T6N,R25W, sec 16
8. 2500', N.Slope, Mossback Ridge, T6N,R25W, sec 23NW
9. 2675' (2620'), Radio Tower Rd., T6N,R25W, Sec 21SE
10. 2400' (2370'), East End Rec. Area, T6N,R25W, sec 24SE

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	LOCALITIES	DATES
APATELODIDAE		
Apatelodes torrefacta (J.E. Smith)	2,3	Jy2,A1
Olceclostera angelica (Grt.) *	1-3	M2,Jn1,Jy2
ARCTIIDAE		
Apantesis anna (Grt.)	1,4	M2
Apantesis figurata (Drury)	1,4,5,7	M2
Apantesis nais (Drury)	1	M2
Cisseps fulvicollis (Hbn.)	4,5,7	M2
Cisthene packardii (Grt.)	4	M2
Clemensia albata Pack.	1,3	M
Crambidia sp.	10	Jn1
Cycnia tenera Hbn.	5	M2
Halysidota tessellaris (J.E. Smith)	2	Jn2
Haploa contigua (Wlk)	2	Jn2
Haploa reversa (Stretch)	2	Jn
Holomelina aurantiaca (Hbn.)	1,4	M2
Holomelina laeta (Guer.-Meneville) *	1	M2
Holomelina opella (Grt.)	1,7	M2
Hyphantria cunea (Drury)	2,6	Jn2
Hypoprepia miniata (Kby.)	1,2,3,4,10	Jn,Jy,A
Spilosoma congrua Wlk.	1	M2
Spilosoma virginica (F.)	10	Jn1
DREPANIDAE		
Oreta rosea (Wlk.)	3	Jy2
EPIPLEMIDAE		
Callizzia amorata Pack.	1	M2
GEOMETRIDAE		
Anacamptodes vellivolata (Hulst)	1	M2
Anavitrinella pampinaria (Gn.)	1-3	M2,Jn2,A
Antepione thisoaria (Gn.)	2,3	Jn2,A2
Besma quercivoraria (Gn.)	1,2,4	M2,Jn2,A2
Cabera quadrifasciaria (Packard)	1	M2
Campaea perlata (Gn.) ? *	5,7	M2
Chlorochlamys chloroleucaria (Gn.)	4,7	M2
Cyclophora pendulinaria (Gn.)	5	Jn1
Dichorda iridaria (Gn.)	3	Jy1
Ectropis crepuscularia (D. & S.)	2,3,5	Jn,Jy2,A
Eubaphe mendica (Wlk.)	1	M2
Euchlaena pectinaria (D. & S.)	2-4	Jy,A
Euchlaena tigrinaria (Gn.)	1,4	M2
Eulithis diversilineata (Hbn.)	3	Jy1,A2
Eupithecia miserulata Grt.	1	M2
Eusarca confusaria Hbn.	5	Jn1
Eutrapela clemataria (J.E. Smith)	2	A
Exelis dicolus Rindge		
Glena cribrataria (Gn.)	1,3	M2,A2
Glenoides texanaria (Hulst)		
Heliomata cycladata (G. & R.)	1,4,7,9	M2
Horisme intestinata (Gn.)	1	M2
Hypagyrtis unipunctata (Haw.)	1-3	M2,Jy2,A
Idaea furciferata (Pack)	2	Jy1
Idaea obfusaria (Wlk.)	2	Jy1
Iridopsis larvaria (Gn.) *	2	Jn2
Itame pustularia (Gn.) *	2	Jn2
Itame subcessaria (Wlk.) *	3	Jn1
Lambdina fiscellaria (Gn.)	2-4	M2,Jn
Lomographa vestaliata (Gn.)	1,2,4,7,8	M2,Jy2
Lytrosis unitaria (H.-S.)	2	Jn2
Melanolophia signataria (Wlk.)	3	A1
Metarranthis duaria (Gn.) *	2	Jn1
Metarranthis homuraria (G. & R.)	1,3	M2,A2
Metarranthis hypocharia (H.-S.) *	2	Jn2
Nemoria sp.	2	Jy1
Orthonama centrostrigaria (Woll.)	1,2,4,8	M2,Jn2
Orthonama obstipata (F.)	1,2,4,5,7	M2
Patalene olyzonaria (Wlk.)	1-3	M2,Jy2
Pero sp.	2	A1
Plagodis alcoolaria (Gn.) *	1-3	M2,Jy2,A1
Plagodis fervidaria (H.-S.)	1	M2
Pleuroprucha insulsaria (Gn.)	1,3,5	M2,Jy1
Probole amicaria (H.-S.) *	1,3,4,7,8	M2,Jn1
Prochoerodes transversata (Drury)	1,2	Jn2
Protoboarmia porcelaria (Gn.)	1,2,5	M2,Jn2
Scopula limboundata (Haw.)	1,7	M2
Selenia kentaria (G. & R.) *	3	Jy2
Semiothisa bicolorata (F.)	1,2,7	M2,Jn2,A2
Semiothisa continuata (Wlk.)	2	Jn2
Semiothisa eremiata (Hulst) *	2	Jn1
Semiothisa multilineata (Pack.)	2,4	M2,Jn2
Semiothisa ocellinata (Gn.)	1-3,5,7,8	M2-A
Semiothisa promiscuata Fgn.	1,7	M2
Semiothisa transitaria (Wlk.)	4	M2
Synchlora frondaria Gn.	1,8	M2
Tetracis cachexiata (Gn.)	1,4,5	M2
LASIOCAMPIDAE		
Malacosoma americanum (F.)	1,4,8,10	M2,Jn1
MIMALLONIDAE		
Lacosoma chiridota Grt.	1	M2
NOCTUIDAE		
Abagrotis alternata (Grt.)	2-4	Jy,A
Acronicta afflicta Grt.	1,4,7	M2
Acronicta americana Harr.	2,4	Jn1,Jy2,A2
Acronicta funeralis G. & R. *	4	A
Acronicta furcifera Gn.	4	M2
Acronicta haesitata (Grt.)	1,2,4,5,7,8	M2,Jn,Jy1,A
Acronicta hasta Gn.	2,4	Jn1,A2
Acronicta impleta Wlk.	4,7	M2,Jn1
Acronicta inclard Sm.	1,2,7,9	M2,A1
Acronicta increta Morr.	1,3,7	M2,A2
Acronicta lithospila Grt.	4	M2
Acronicta lobeliae Gn.	1,5	M2
Acronicta morula G.& R.	2-4	M2,Jn1,A2
Acronicta ovata Grt.	2-4	Jn,A
Acronicta radcliffei (Harv.)	2	Jn2
Acronicta spinigera Gn.	1,7	M2
Acronicta tritona (Hbn.)	1-3	M2,Jn1,A
Agrapha oxygramma (Gey.)	10	Jn2
Agriopodes fallax (H.-S.)	1	M2
Agriopodes teratophora (H.-S.)	1	M2
Agrotis ipsilon (Hufn.)	1,2	M2,Jn1
Allotria elonympha (Hbn.)	1,4,5,7	M2
Amphipyra pyramidoides Gn.	2	Jn1
Anagrapha falcifera (Kby.)	1,2	M2
Anorthodes tarda (Gn.)	1,4,5,8	M2
Apamea lignicolora (Gn.)	4	M2
Argyrostrotis anilis (Drury)	1	M2
Arugisa latiorella (Wlk.)	10	Jn1
Autographa biloba Steph.	4	Jn1
Baileya australis (Grt.)	10	Jn2
Baileya dormitans (Gn.)	6	Jn2
Baileya opthalmica (Gn.)	1,3,9	M2,Jy2
Balsa labecula (Grt.)	2	Jn2
Bleptina caradrinalis Gn.	1,4,5,7,8	M2
Bleptina inferior Grt.	1,4	M2
Bleptina sangamonia B. & McD.	1	M2
Bomolocha abalienalis (Wlk.)	3	A1
Bomolocha baltimoralis (Gn.)	2,4	A2
Bomolocha bijugalis (Wlk.)	2	A2
Bomolocha madefactalis (Gn.)	1-3,6	Jn,A2
Bomolocha manalis (Wlk.)	1	M2

Bomolocha palparia (Wlk.)	1-3	Jn,Jy2
Bulla deducta (Morr.) *	2	Jn2
Cataocala amestris Stkr.	2	Jn2,Jy1
Catocala amica (Hbn.)	1,2,3	Jn2,Jy
Catocala andromedae (Gn.)	1,2	Jn2,Jy1
Catocala cerogama Gn. *	2	Jy1
Catocala coccinata	2	Jn2,Jy2
Catocala crataegi Saunders	2	Jy1
Catocala dejecta Stkr.	2,3,4	Jn2,Jy2,A
Catocala epione (Drury)	2	Jn2,Jy1
Catocala gracilis Edw.	1,2	Jn2,Jy1
Catocala ilia (Cram.)	1,2,4	Jn,Jy1
Catocala lacrymosa Gn.	2,3	Jy2,A
Catocala micronympha Gn.	2	Jn2,Jy1
Catocala palaeogama Gn. ?	4	A
Catocala residua Grt. *	1	Jn2
Catocala retecta Grt.	2,3,4	A
Catocala ulalume Str.	2	Jy1
Caenurgia chloropha (Hbn.)	2	Jn2
Caenurgina erechtea (Cram.)	2,4,10	M2,Jn
Callopistria mollissima (Gn.)	1	M2
Cerma cerintha (Tr.)	3	Jy1
Charadra deridans (Gn.)	2	Jy1
Chrysanympha formosa (Grt.) *	1	M2
Chytonix palliatricula (Gn.)	1,2,4,5,7,8	M2,Jn1
Cirrhophanus n.sp.	7	M2
Cobubatha sp.	1	M2
Colobochyla interpuncta (Grt.)	1	M2
Cosmia calami (Harv.)	2	Jy1
Cucullia speyeri Lint. *	4	M2
Elaphria chalcedonia (Hbn.)	4	M2
Elaphria festivoides (Gn.)	1	M2
Elaphria grata (Hbn.)	1,8	M2
Elaphria versicolor (Grt.)	1	M2
Euagrotis illapsa (Wlk.)	1,7	M2
Euclidia cuspidea (Hbn.)	1	M2
Eudryas grata (F.)	2	Jn1
Euparthenos nubilis (Hbn.)	1,5	M2
Feltia subgothica (Haw.)	4	A2
Feltia tricosa (Lint.)	2	A2
Galgula partita (Gn.)	1,5,8	M2
Hemeroplanis scopulepes (Haw.)	1	Jn2
Hemeroplanis sp.	7	M2
Homohadena infixa (Wlk.)	2	Jn
Homophoberia apicosa (Haw.)	1,4	M2
Homorthodes furfurata (Grt.)	1,4	M2
Hyperstrotia secta (Grt.)	1,2,4,5	M2,Jy2
Hyperstrotia villificans (B. & McD.)	1	M2
Hypsoropha hormos Hbn.	1,2,4	M2,Jy2,A2
Hypsoropha monilis (F.)	1	M2
Idia aemula Hbn.	2-4,10	M2,Jn,A
Idia americalis (Gn.)	1-4,5,8	M2,Jy2
Idia lubricalis (Gey.)	2,4	M2,Jn2
Idia rotundalis (Wlk.)	1,2	M2,Jy1
Iodopepla u-album (Gn.)	1	M2
Isogona tenuis (Grt.)	1	M2
Lacinipolia anguina (Grt.)	1	M2
Lacinipolia lorea (Gn.) *	2	Jn1
Lacinipolia renigera (Steph.)	1,4,7,8	M2
Ledaea perditalis (Wlk.)	1	M2
Lesmone detrahens (Wlk.)	1,4,5	M2
Leucania sp.	1,10	M2,Jn1
Leuconycta n. sp.	2	Jn2
Lithacodia carneola (Gn.)	1	M2
Lithacodia concinnimacula Gn. *	1,8	M2
Lithacodia muscosula (Gn.)	4	M2
Marathyssa basalis (Wlk.)	4	M2
Marathyssa inficita (Wlk.)	1,4,8	M2
Metalectra discalis (Grt.)	1	M2
Mocis texana (Morr.)	1-4,7	M2,Jy2,A2
Nedra ramosula (Gn.)	2,4	M2,A1
Nola pustulata (Wlk.)	1,7	M2
Ogdoconta cinereola (Gn.)	1,3,4	M2,Jy2
Ozarba nebula B. & McD. *	1	M2
Paectes abrostoloides (Gn.)	1	M2
Paectes flabella (Grt.)	1,4	M2
Paectes oculatrix (Gn.)	1	M2
Palthis angulalis (Hbn.)	1,3,4	M2,A2
Palthis asopialis (Gn.)	1,5,10	M2
Pangrapta decoralis Hbn.)	1-4,10	M2,Jn,A1
Panopoda carneicosta Gn.	1-7	M2,Jn-A
Panopoda rufimargo (Hbn.)	1,2,4,5,10	M2,Jn,Jy1,A
Parallelia bistriaris Hbn.	1	M2,Jn2
Peridroma saucia (Hbn.)	1,2,4-6,10	M2,Jn
Phalaenostola larentioides Grt.	10	Jn1
Phosphila miselioides (Gn.)	1,2,4,5,10	M2,Jn
Plathypena scabra (F.)	1,2,5,8	M2,Jn2,A
Platysenta sutor (Gn.)	5	M2
Platysenta vecors (Gn.)	1-4,8	M2,A
Plusiodonta compressipalpis Gn.	3,4	Jy1,A2
Polia detracta (Wlk.)	1,2,3,4,5,10	M2,Jn1
Polia latex (Gn.)	1	M2
Polychrysia morigera (Hy. Edw.) *	8	M2
Polygrammate hebraeicum Hbn.	1,5,7	M2
Protolampra brunneicollis (Grt.)	1,2,4	M2,Jn,Jy1
Protoperigea n.sp.	1,4	M2
Pseudaletia unipuncta (Haw.)	2,3,4,5	M2,Jn1,A2
Rachiplusia ou (Gn.)	2,6	Jn2
Renia fraternalis Sm.	1,4,7,9	M2
Rhynchagrotis sp. nr. cupida (Grt.)	2	Jn2
Scolecocampa liburna (Gey.)	2,3	Jn,Jy1
Spiloloma lunilinea (Grt.)	4	A2
Spodoptera ornithogalli (Gn.)	1,2,3,4,5,8	M2,Jn,Jy2
Spragueia leo (Gn.)	2	Jn2,Jy1
Tarachidia candefacta (Hbn.)	1	M2
Thioptera nigrofimbria (Gn.)	1,3,5	M2,Jy2
Tricholita signata (Wlk.)	3	A1
Xestia dolosa Franc.	1	M2
Zale aeruginosa (Gn.)	1	M2
Zale horrida Hbn.	1	M2
Zale lunata (Dru.)	1,2,5	M2,Jn2
Zale minera (Gn.)	1,2,3	M2,Jn2,Jy2
Zale undularis (Dru.)	1,2,6	M2,Jn
Zale unilineata (Grt.)	1	M2
Zanclognatha cruralis (Gn.)	1,4	M2
Zanclognatha jacchusalis (Wlk.)	1	M2
Zanclognatha obscuripennis (Grt.)	4	M2
Zanclognatha pedipilalis (Gn.) *	1,10	M2,Jn1
Zanclognatha n. sp.	2	Jn2
NOTODONTIDAE		
Datana angusii G. & R.	3	Jy2
Datana ministra (Drury)	4	A2
Ellida caniplaga (Wlk.)	3,6	Jn2,A1
Furcula borealis (Guer.-Meneville) *	2	A2
Heterocampa biundata (Wlk.)	2,3,10	Jn,Jy1,A1
Heterocampa obliqua Pack.	1,2	Jn2,A1
Heterocampa umbrata Wlk.	1	M2
Hyperaeschra georgica (H.-S.)	1,2,4	M2,Jn2,A
Lochmaeus bilineata (Pack)	1,3	M2,A1
Lochmaeus manteo Doubleday	3,4	M2,A1
Macrurocampa marthesia (Cram.)	1,2,4	M2,Jn1,A
Nadata gibbosa (J.E. Smith)	1,5	M2
Nerice bidentata Wlk.	3	Jy1,A1
Oligocentria lignicolor (Wlk.)	4	M2
Oligocentria semirufescens (Wlk.)	2	Jn1,A2
Peridea angulosa (J.E. Smith)	2,5	M2,Jy,A
Peridea basitriens (Wlk.) *	3,7	M2,A2

Schizura leptinoides (Grt.)	1,2	M2,Jy1
Schizura unicornis (J.E. Smith)	4	M2
SATURNIIDAE		
Actias luna (L.)	1,2,4	JN1,A
Anisota stigma (F.)	3	Jy2
Antheraea polyphemus (Cram.)	2,3	Jn1,Jy2
Automeris io (F.)	1	Jn1,A
Citheronia regalis (F.)	3	A2
Eacles imperialis (Drury)	2,3,4	A
Hyalophora cecropia (L.)	2	Jn1
SPHINGIDAE		
Darapsa myron (Cram.)	2,3,6,10	Jn2,Jy2,A
Darapsa pholus (Cram.)	1,4	Jn1
Deidamia inscripta (Harr.)	1	Jn1
Laothoe juglandis (J.E. Smith)	2,4,5	M2,Jn2,A2
Paonias astylus (Drury) *	1,2,4	Jn2,A
Paonias excaecatus (J.E. Smith)	5,9	M2
Paonias myops (J.E. Smith)	1	Jn1
Smerinthus jamaicensis (Drury)	1	Jn1
Sphinx chersis (Hbn.)	4,6	Jn2

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PLEISTOCENE MAMMALS FROM THE SOUTH SULPHUR RIVER, HUNT COUNTY, TEXAS

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ABSTRACT

Preliminary collecting and excavating along the South Sulphur River has produced a diverse list of fossil mammals. The pampathere, *Holmesina septentrionalis*, and the large armadillo, *Dasypus bellus*, with their southern affinities from the extinct megafauna, were found in association with *Microtus pennsylvanicus*, which has a northern distribution at present. This combination of species argues for climatic conditions and biotic communities during the Pleistocene that have no modern counterparts.

INTRODUCTION

One of us (LCD) has been collecting fossils along the South Sulphur River south and southwest of Commerce, Hunt County, Texas, since 1984. Although the focus was originally upon Cretaceous fish remains, several Pleistocene mammal fossils were collected through time. Efforts to measure the efficiency of collecting the bones and teeth have been reported (Ball and Davis, 1991).

The fossils are derived from Pleistocene and Recent sediments upon a Cretaceous bedrock of limestone or shale. Nothing has been noted to indicate the sediments differ in any major way from those described by Slaughter and Hoover (1963) from the North Sulphur River roughly 20 airline miles away to the northeast. As at the Ben Franklin quarries, river channelization has resulted in downcutting by 20 feet or more, freeing the fossils from their matrix. Gravel bars exposed during periods of low rainfall have been the chief source of the fossils reported in this study. In an attempt to deal only with Pleistocene materials, we have selected only those specimens which show some discoloration, particularly brown staining.

CHECKLIST OF FOSSIL MAMMALS OF THE SOUTH SULPHUR RIVER

Order Edentata
- *Holmesina septentrionalis*
- *Dasypus bellus*

Order Carnivora
- *Lynx rufus*
- *Taxidea taxus*

Order Rodentia
- *Castoroides ohioensis*
- *Castor canadensis*
- *Ondatra zibethicus*
- *Microtus pennsylvanicus*
- *Pitymys pinetorum* ?
- *Synaptomys cooperi*
- *Neotoma micropus* ?
- *Geomys bursarius*

Order Lagomorpha
- *Sylvilagus* sp.

Order Perissodactyla
- *Equus* sp.

Order Artiodactyla
- *Odocoileus virginianus*
- *Mylohyus nasutus*
- *Bison* sp.

Order Proboscidea
- *Mammuthus* sp.
- *Mammut americanum*

NOTES ON SPECIES

Holmesina septentrionalis

Referred specimens. One buckler osteoderm, one buckler or band osteoderm.

Discussion. This species is identified by the sculpturing around the perimeter of the external surface. One specimen, an irregular seven-sided polygon, is 8.7 mm thick and measures 44.1 mm by 39.9 mm. The other specimen tentatively assigned to this taxon is broken and abraded but appears to be the posterior part of an osteoderm from either the posterior row of the pectoral buckler (Fig. 7, Edmund, 1985) or the anterior row of a pelvic buckler (Fig. 8, Edmund, 1985).

The species has been recovered from 65 localities in the southeastern United States with Kanopolis, Kansas, being the northernmost record (Kurten and Anderson, 1980).

Dasypus bellus

Referred specimens. Seven buckler osteoderms, one band osteoderm.

Discussion. This species is recognizable by the characteristic sculpturing upon the armoring osteoderms. The band osteoderm is larger in width and thickness than the average of 194 osteoderms reported by Martin (Fig. 3.1, 1974). The buckler specimens have an average thickness of 4.8 mm.

This species ranged from Blackwater Draw, New Mexico (Harris, 1985) to Florida (Martin, 1974) and as far north as western Iowa (Rhodes, 1984). Its distribution was apparently limited by the availability of insects year round. Its presence indicates a climate no more severe than in north-central Texas today and a rainfall of more than 20 inches per year (Slaughter, 1961).

Lynx rufus

Referred specimens. Left ml.

Discussion. The specimen has a width of 5.0 mm (vs. 4.8 mm in a modern specimen from Newton County, Arkansas) and an anterior to posterior length of 11.1 mm (vs. 10.6 mm in the modern specimen). The length from the crown to the tip of the root measures 15.8 mm. The exposed enamel measures 6.2 mm vertically (vs. 5.8 mm in the modern specimen).

The bobcat is a common mammal in Pleistocene deposits, having been recovered in over 60 Rancholabrean sites from California to Florida, including Texas and Arkansas. The fossil record extends from the Blancan through the Recent.

The bobcat inhabits a wide range of environments, from desert to swamps. Rodents and rabbits make up a large percentage of its diet.

Taxidea taxus

Referred specimens. Olecranon process of the right ulna.

Discussion. The fossil bone and a Recent badger ulna differ only in the degree of development of muscle attachment ridges. The fossil ulna probably came from an older individual than the Recent speciman at hand.

This medium-sized carnivore prefers grasslands and a diet of rodents.

Castoroides ohioensis

Referred specimens. Enamel fragment from an incisor.

Discussion. The fragment measures 12.8 mm by 14.3 mm and has the

fluted pattern present on the anterolateral surface of *Castoroides ohioensis* incisors. Seven ridges are present within the 14.3 mm section of enamel. There are five flutes in a distance of one centimeter across the fossil specimen. This spacing of flutes matches that on a cast of a *Casteroides* incisor.

During the Pleistocene, the giant beaver was the largest rodent in North America. It inhabited lakes and ponds bordered by swamps. There is no evidence that it cut trees and built dams. Its diet consisted of swamp vegetation. Fossils of the giant beaver have been found from Alaska south to Florida and from Nebraska east (Kurten and Anderson, 1980).

Castor canadensis

Referred specimens. Seven molars, one incisor.

Discussion. Color variation of the molars range from white to a permineralized brown, the latter specimens being of presumably greater age. The average size of the seven molars is 20.9 mm in vertical length by 7.3 mm anterior to posterior length by 6.9 mm width. The beaver incisor is 27.8 mm (vertical length) by 7.3 mm (anterior to posterior length) by 5.4 mm (width).

The earliest record of *Castor canadensis* is late Blancan. Beavers are large aquatic herbivorous rodents that are abundant along the waterways of North America excluding southern Florida.

Ondatra ziebethicus

Referred specimens. Twelve molars.

Discussion. When the lengths and widths of three lower first molars are measured and plotted using the Nelson and Semken technique (Fig. 1, 1970), the molars suggest an age no older than Wisconsinan. However, if dentine tract heights alone are considered, two specimens seem to fit with the Illinoian distribution (Fig. 2).

Microtus pennsylvanicus

Referred specimens. Two right ml.

Discussion. The specimens display the characteristic five closed enamel triangles of the meadow vole with a sixth triangle that is nearly closed. The species has the largest range of any American *Microtus* but presently lives no closer to Hunt County, Texas, than northwest New Mexico or northern Missouri (Reich, 1981). Fossil specimens of *M. pennsylvanicus* have been recovered from Pleistocene sediments in Texas, Oklahoma, and Louisiana (Martin, 1968).

It prefers grasslands, particularly moist areas, but can also be found in woodlands (Burt and Grossenheider, 1964).

Pitymys pinetorum

Referred specimens. Left lower jaw with m1-m3, left ml.

Discussion. The isolated ml is a fragment that is interpreted as being an anterior trefoil with two confluent triangles. The jaw fragment is referred to this taxon on the basis of the tightness of closure of the fifth and sixth triangles from the anterior trefoil such as is seen in *Pitymys*. By comparison there is incomplete closure, allowing some dentine between the opposite plates of enamel, in *Microtus ochrogaster*. This distinction is not infallible, but *Pitymys* does live in Hunt County, Texas today. The closest places *M. ochrogaster* lives to the find site are central Oklahoma and southeast Texas.

The pine vole is characteristically found in forests or orchards.

Synaptomys cooperi

Referred specimens. Right M1.

Discussion. The specimen displays the deep enamel re-entrants, which pass from one side of the tooth to the other, characteristic of this genus. The tooth lacks the anterior loop but resembles the enamel pattern of a *S. cooperi* figured by Guilday *et al.* (Fig. 19, 1964). At 1.5 mm wide, it is slightly larger than their New Paris No. 4 material. They stated that *Synaptomys* exhibits a negative Bergmann's response, and their specimens correlated best with the small forms in eastern Canada. The more southerly Sulphur River form would be expected to be larger.

The southern bog lemming occupies low, damp bogs and meadows with heavy growth of vegetation. Those populations living in northeast Arkansas would be the closest to the find site.

Neotoma micropus ?

Referred specimens. Right m2, left M2, and one molar fragment.

Discussion. The genus *Neotoma* can be recognized by its rooted molars with thick enamel covering. The right m2 more closely resembles a specimen of *N. micropus* at hand than the molars of three *N. floridana* since it has an inflated rather than a compressed posterior loop, and the posterior border of its middle labial salient is perpendicular to the long axis of the tooth. The identity of the tooth remains uncertain since it has been compared with only a small number of modern specimens, but there seem to be no distinguishing features at all on the left M2.

The southern plains wood rat, *N. micropus*, lives in western Texas, Oklahoma, and most of New Mexico while the eastern wood rat, *M. floridana*, lives in Hunt County today.

Geomys bursarius

Referred specimens. Three upper left incisors, two upper right incisors, three upper premolars.

Discussion. The plains pocket gopher is identifiable by a small, shallow groove medial to a wider, deeper groove running the length of the upper incisors. The premolars of *Geomys* are recognized by a pair of squared enamel re-entrants that nearly bisect the tooth.

Geomys is a burrower and is seldom seen above ground. It prefers grasslands such as pastures, roadsides, and railroad rights-of-way (Burt and Grossenheider, 1964).

Sylvilagus sp.

Referred specimens. Two upper molars, one lower second premolar.

Discussion. The specimens can be matched for size and gross structure by teeth of *Sylvilagus floridanus*, but they have not been compared to other species of the genus, such as the swamp rabbit which also lives in the area of the find site. Both species prefer some brush in their habitat and can live in marshy or swampy areas.

Equus sp.

Referred specimens. Six molar fragments.

Discussion. The six fragments have lengths of 64 mm, 53 mm, 38 mm, 87 mm, 58.5 mm, 28.5 mm and display complex enamel foldings. They are referred to *Equus*, but no complete teeth were recovered from the study area, and no attempt is made to assign the fossils to any particular species.

Odocoileus virginianus

Referred specimens. Left m1, right m3, left p2, left P3.

Discussion. The specimens were identified by comparing them with the dentition of a modern *Odocoileus virginianus*.

The white-tailed deer is first found in late Blancan and continues in the stratigraphy to the present. This species is an inhabitant of woodlands, forest edges, and bottomlands. It forages on trees and shrubs, with acorns also being an important food source.

Mylohyus nasutus

Referred specimen. One molar.

Discussion. The specimen is nearly square with four cusps worn down to expose the dentine. All four roots, one of them broken, are preserved. In the absence of comparative material, no ettempt has been made to determine which molar is present. It is the belief of Kurten and Anderson (1980) that this is the only species of long-nosed peccary in the eastern and central United States in Rancholabrean times.

Bison sp.

Referred specimen. One large selenodont molar fragment.

Discussion. The tooth fragment, 34.0 mm length by 17.6 mm width, as preserved, is appreciably larger than the specimens assigned to the white-tailed deer. We are aware of the difficulty in separating *Bison* teeth from those of *Bos*, but the specimen shows the degree of staining characteristic of other Pleistocene specimens from the South Sulphur River.

Mammuthus sp.

Referred specimens. 28 chips of enamel.

Discussion. These fragments have enamel thicknesses in excess of two millimeters with a linear pattern of corrugations and lumps. Only one fragment preserves two parallel enamel plates, 4.4 millimeters apart, for a total maximum thickness of 7.1 mm.

The parallel plates of enamel perpendicular to the occlusal surface have been regarded as evidence that these animals were grazers.

Mammut americanum

Referred specimens. Two blocks of enamel.

Discussion. These fragments preserve the rounded cusp pattern of these browsing proboscidians, and the enamel is more than five millimeters thick.

DISCUSSION

Interpretation of the South Sulphur River (hereafter, S.S.R.) fossils is complicated by their not having been found in place, but their similarity to the Ben Franklin local fauna (Slaughter and Hoover, 1963) from 20 miles away on the North Sulphur River is unmistakable. The two faunas share 15 or 16 species. We also recovered *Sigmodon hispidus* teeth but did not include the specimens because they appeared too young. The *Holmesina pampathere,* badger, beaver, and bobcat of this paper were not recovered in the Ben Franklin fauna, and we did not recover the *Sorex cinereus, Blarina* sp., *Spermophilus franklini, Reithrodontomys* sp., *Canis latrans* or ?*Antilocapra americana* that Slaughter and Hoover obtained by removing and washing "several tons of matrix."

One line of evidence that the S.S.R. species were contemporaries is the fact that all the extant species include one region of northeastern Kansas and northwestern Missouri within their present distributions (share an area of sympatry). This area along the Missouri River valley is determined by the southern border of *Microtus pennsylvanicus* and the northern occurrence of *Neotoma* sp. The question as to the proper identity of the microtine m1 with three closed triangles is not, then, a critical factor in interpreting the fauna. An area of sympatry for all 10 forms except *Geomys* can be mapped in southwestern Ohio, and all species except *Pitymys* can be located in southwestern Colorado. Since all these areas are north of the find site, it might be argued that the faunal changes down to the present have been mostly the loss of megafauna species and the retreat of certain species northward. If this retreat has been due to intolerance for the hottest days of summer (Slaughter and Hoover, 1963), it would follow that summer temperatures in Hunt County were cooler at the time the remains of the S.S.R. species were being preserved.

The presence of *Sorex cinereus* in the Ben Franklin local fauna prevents any area of sympatry from being mapped. The southern limit of the distribution of the masked shrew does pass within one hundred miles of the Kansas-Missouri area of sympatry identified above. The presence of this shrew is a further indication of cooler summer temperatures. At the same time, the presence of *Dasypus bellus* in both collections and *Holmesina* in the S.S.R. collection suggests that winter temperatures were not exceedingly low if we can rely on the present distribution of armadillos as an index to their intolerance of frigid conditions.

SUMMARY

At least 19 species of mammals have been recovered from gravel bars of the South Sulphur River, and six are members of the extinct Pleistocene megafauna. The collection is similar to the Ben Franklin local fauna recovered 20 miles away on the North Sulphur River. The areas of sympatry for both faunas suggest a climate that was cooler when the fossils were being deposited than the present. The absence of extremely high summer daytime temperatures would have allowed micro-mammals that are presently northern-distributed to have occupied northeast Texas during the Late Pleistocene.

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SPIDERS COLLECTED IN SOUTHEAST ARKANSAS BY THE PIT TRAP METHOD

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ABSTRACT

By employing the pit-trap method, thousands of spiders were collected from primarily pine-hardwood stands which had undergone different forestry treatments in Bradley and Drew counties. Fourteen families and 120 species of spiders were collected, two of which were new state records.

INTRODUCTION

In Arkansas, spiders have rarely been collected by means of pitfall traps (Heiss, 1977 and Dorris and Thompson, 1986). If large areas of the state are researched, it is difficult to check traps frequently. This study was made over only two counties so that traps could be checked weekly during a four year period from 1984-1988. The purpose of this research is two-fold: to determine species captured by the pit-trap method and to determine whether new additions can be added to the state record. A future paper will address species differences in various forestry treatment practices.

METHODS AND MATERIALS

Pitfall traps with rain covers were constructed in the following way: A 16 oz. plastic drinking cup was placed in a 1 quart metal oil can opened at both ends and inserted into a hole in the ground. The cup contained 5 fl. oz. of a 1:1 mixture of antifreeze (ethylene glycol) and water. The cup could be easily removed and contents placed in baby food jars for transportation to the laboratory where identifications were made with a stereoscopic microscope. A 1 ft. square plywood rain lid, held 1 in. over the cup with rocks or wood blocks., reduced the amount of rain entering the trap. Traps were emptied weekly, sorted by forest treatment, and placed in 80% ethyl alcohol. Weekly collections from all traps within each treatment area were pooled for storage. Specimens were later identified and placed in screw cap vials of 70% alcohol and placed in spider storage cabinets. Taxonomic names used here are those employed by Gertsch (1979), Comstock (1982), Kaston (1978), and Heiss and Allen (1986). Species are listed alphabetically and families are in the phylogenetic order used by Kaston.

RESULTS

Thousands of spiders were collected with families of ground spiders such as Gnaphosidae and Lycosidae being the most numerous. Two new species for Arkansas were revealed bringing the total number of species for Arkansas to 509. New species for the state are identified with an asterisk. From the 1984-1988 collections 14 families and 120 species of spiders have been identified from pitfall traps located in Bradley and Drew counties. They are as follows:

ANTRODIAETIDAE
- *Antrodiaetus unicolor* (Hentz)

THERIDIIDAE
- *Latrodectus mactans* (Fabricius)

ARANEIDAE
- *Aranea cavatica* (Keyserling)
- *Aranea nordmanni* (Thorell)
- *Eustala anastera* (Walckenaer)
- *Mangora gibberosa* (Hentz)
- *Micrathena sagittata* (Walckenaer)
- *Neoscona arabesca* (Walckenaer)

AGELENIDAE
- *Agelenopsis naevia* (Walckenaer)
- *Agelenopsis pennsylvanica* (C. L. Koch)
- *Coras medicinalis* (Hentz)

PISAURIDAE
- *Dolomedes vittatus* (Walckenaer)

HAHNIIDAE
- *Neoantistea agilis* Keyserling

LYCOSIDAE
- *Allocosa funerea* (Hentz)
- *Arctosa emertoni* Gertsch
- *Arctosa rubicunda* (Keyserling)
- *Arctosa virgo* (Chamberlin)
- *Lycosa antelucana* Montgomery
- *Lycosa aspersa* Hentz
- *Lycosa carolinensis* Walckenaer
- *Lycosa frondicola* Emerton
- *Lycosa gulosa* Walckenaer
- *Lycosa helluo* Walckenaer
- *Lycosa punctulata* (Hentz)
- *Lycosa rabida* Walckenaer
- *Lycosa riparia* (Hentz)
- *Pardosa milvina* (Hentz)
- *Pardosa distincta* (Blackwall)
- *Pardosa moesta* Banks
- *Pardosa ramulosa* (Hentz)
- *Pirata insularis* Emerton
- *Pirata maculatus* Emerton
- *Pirata minutus* Emerton
- *Pirata piratica* (Clerk)
- *Paradosa saxatilis* (Hentz)
- *Schizocosa avida* (Walckenaer)
- *Schizocosa bilineata* (Emerton)
- *Schizocosa crassipes* (Walckenaer)
- *Schizocosa ocreata* (Hentz)
- *Schizocosa saltatrix* Walckenaer
- **Sossipus mimus* Chamberlin
- *Tarentula aculeata* (Clerk)
- *Tarentula kochi* Keyserling
- *Trabea aurantiaca* (Emerton)
- *Trachosa pratensis* (Emerton)
- *Trochosa terricola* (Thorell)

OXYOPIDAE
- *Oxyopes salticus* Hentz
- *Peucetia viridans* (Hentz)

GNAPHOSIDAE
- *Callilepis imbecilla* (Keyserling)
- *Callilepis pluto* Banks
- *Cesona bilineata* (Hentz)
- *Drassodes auriculoides* Barrows

Drassodes neglectus (Keyserling)
Drassodes robinsoni Hentz
Drassyllus creolus Chamberlin & Gertsch
Drassyllus covensis Exline
Drassyllus aprilinus Banks
Drassyllus depressus (Emerton)
Drassyllus dixinus Chamberlin
Drassyllus ellipes Chamberlin & Ivie
Drassyllus gynosaphes Chamberlin
Drassyllus niger (Banks)
Drassyllus virginianus Chamberlin
Gnaphosa muscorum (L. Koch)
Gnaphosa sericata (L. Koch)
Herpyllus ecclesiasticus (Hentz)
Litophyllus temporarius Chamberlin
Poecilochroa capulata (Walckenaer)
Rachodrassus exlineae Platnick & Shadab
Synaphosa paludis (Chamberlin & Gertsch)
Zelotes duplex (Chamberlin)
Zelotes hentzi (Barrows)
Zelotes laccus (Barrows)
Zelotes rusticus (L. Koch)
Zelotes subterraneus (C. L. Koch)

CLUBIONIDAE
Castianeira amonea (C. L. Koch)
Castianeira cingulata (C. L. Koch)
Castianeira descripta (Hentz)
Castianeira gertschi Kaston
Castianeira trilineata (Hentz)
Castianeira lenta (Hentz)
Castianeira longipalpus (Hentz)
Clubiona excepta Koch
Clubiona pallens Hentz
Marcellina piscatoria (Hentz)
Micaria aurata (Hentz)
Phrurotimpus formica Banks
Strotarchus piscatoria (Hentz)

ANYPHAENIDAE
Anyphaena celer (Hentz)
Aysha gracillis (Hentz)

ZORIDAE
Zora punila (Hentz)

THOMISIDAE
Coriarachne floridana Banks
Coriarachne lenta (Walckenaer)
Misumenoides formosipes (Walckenaer)
Misumenoides sericata (Walckenaer)
Misumenops asperatus (Hentz)
Misumenops celer (Hentz)
Misumenops oblongus (Keyserling)
Oxyptila americana Banks
Oxyptila conspurcata Thorell
Synema parvula (Hentz)
Xysticus elegans Keyserling
Xysticus gulosus Keyserling
Xysticus luctans (C.L. Koch)
Xysticus transversatus (Walckenaer)
Xysticus triguttatus Keyserling
Xysticus tumefactus (Walckenaer)

SALTICIDAE
Eris aurantia (Lucas)
Eris marginatus (Walckenaer)
Habrocestum pulex (Hentz)
Habronattus decorus (Blackwall)
Maevia inclemens (Walckenaer)
Metacyrba taeniola (Hentz)
Metaphidippus exiguus (Banks)
Metaphidippus galathea (Walckenaer)
Metaphidippus manni (G. & E. Peckham)
Neon nelli Peckham
Phidippus audax (Hentz)
Phlegra fasciata (Hahn)
**Plexippus paykulli* (Audouin)

DISCUSSION

As was expected, the most numerous spiders collected in the pit traps were of the families, Gnaphosidae (ground spiders) and Lycosidae (wolf spiders). Other species found in large numbers included the family Thomisidae (crab spiders). These families of wandering spiders are more likely to fall into pitfall traps than families of spiders that construct webs to trap prey. New records for the state were *Sossipus mimus* Chamberlin, a lycosid and *Plexippus paykulli* (Audouin), a salticid. Emphasis on the use of pit traps was expected to yield additional records since this method has rarely been used in Arkansas.

ACKNOWLEDGMENTS

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MICROWAVE PASTEURIZATION OF POTTING MIXES

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ABSTRACT

A study was conducted to determine if potting soils could be pasteurized with a typical 1200 watt microwave oven. Microwave radiation times varied from 0 to 6.0 minutes. Preliminary results indicated that "damping-off" diseases could be prevented in tomato seedlings with the use of potting soils pasteurized by microwaves.

INTRODUCTION

Many home gardening books recommend baking containers of soil before sowing seeds to prevent damping-off diseases (Doty, 1973; Raymond and Raymond, 1978; Williamson, 1975). Damping-off pathogens can be killed by baking potting soil in the oven for 30-45 minutes at 180 degrees Fahrenheit (Roberts, 1981). The baking procedure suggested by these authors is costly, inconvenient, and time consuming for the home gardener. Hansen *et al.* (1990) reported the control of Fusarium and Pythium in nurseries by fumigation with the chemicals chloropicrin and dzaonet. The authors noted that soil fumigation is costly and the chemicals are extremely hazardous. Economic and environmental factors are stimulating interest in alternative strategies for disease suppression.

A microwave oven was used to kill spores of *Bacillus subtilis* (Jeng, 1987). Jeng (1987) found that a treatment of 45 minutes by 2450 MHz microwaves was required to kill spores in dry glass vials at 137°C. Microwave sterilization was a function of field strength and exposure time. The nonthermal effects were not significant in dry microwave sterilization and the sterilization of spores was a function only of thermal effects. Microwave radiation has been found to be effective in the death of soil borne plant pathogens in soil (Ferriss, 1984). The purpose of this experiment was to determine if a microwave oven could be used to pasteurize potting soil mixes to prevent damping-off of tomato seedlings.

MATERIALS AND METHODS

Three potting mixes were tested by microwaving them in a 1200 watt oven at a frequency of 2450 MHz. The potting soil types used were commercial potting soil from Hyponex and Wal-Mart and composted garden waste. Soils (30-55 g) were placed in small peat pots (80 ml) and then placed in the microwave oven for times ranging from 0 to 6.0 minutes. The potting mixes were first moistened with 10 ml of tap water, except where noted. After the soils had cooled, the pots were planted with three (3) seeds. From two to five replications were used. Pepper, melon, and broccoli and gardens oil was examined in nonreplicated experiments. Pots were then placed in a south facing laboratory window and kept at 20-22° Celsius. The soil was kept moist and the pots covered with clear plastic covers to prevent drying. Emergence and seedling survival were recorded over a one month period. Seedlings which died as a result of damping-off were examined under the microscope and the pathogens were identified with the use of monographs from Commonwealth Mycological Institute (1966).

RESULTS

In the replicated experiments, Table 1, ten pots were not treated with microwaves of which 6 pots (60%) were observed to have fungus *Pythium*, no growth, or damping-off. The seedlings were assigned a disease rating (1 = no *Pythium*, 2 = *Pythium* observed on soil or plants, 3 = plant death) and statistically analyzed. A t-test was applied to the disease rating. A null hypothesis of no significant difference between microwaved and nonmicrowaved samples was rejected at the (@) significance level of greater than .01 (t=3.03). A total of 24 pots was microwave treated for times varying from 1.7 to 6.0 minutes in the replicated experiments. Only one microwaved sample was observed to have fungus or damping-off mortality (4.2%). Observation of dead seedlings indicated *Pythium* spp. were the causal agents of damping-off. The results indicate soil pasteurization by microwaves from 1.7 to 6.0 minutes is effective in preventing damping-off in tomatoes.

Table 1. Influence of microwave treatments on tomato seedling emergence in potting soils.

Potting mix	Microwave Time (min)	Moisture (wet = 10 ml)	Disease Rating Exp 1	Exp 2	Exp 3	Mean
Wal-Mart	0	wet	2	2	2	2
	0	wet	2	2		2
	3.4	dry	1	1		1
	3.4	wet	1	3		2
	6.0	dry	1	1		1
	6.0	wet	1	1		1
Composted	0	wet	1	3		2
	4.5	wet	1	1		1
	6.0	wet	1	1		1
Hyponex	0	wet	1	1	1	1
	1.7	wet	1	1	1	1
	4.5	wet	1	1	1	1
	6.0	wet	1	1	1	1

Table 2 is a display of all data with multiple variables when microwaving time was the common variable. Statistical analysis of a t-test applied to this data on the basis of microwaved and nonmicrowaved samples produced a t value of 1.47. This allowed rejection of the null hypothesis (no significant difference between microwaving and nonmicrowaving) at the 0.1 level. Preliminary results indicate soil pasteurization is also effective in preventing damping-off of broccoli, pepper, and melons (data not specifically shown).

Table 2. Data displayed by microwave treatment variable regardless of soil and seed types.

Microwave time (min)	Moisture (wet 10 ml)	Number of trials	Number infected	Percent infected
0	wet	14	7	50
1.7	wet	3	0	0
3.4	dry	2	0	0
3.4	wet	7	1	14
4.5	wet	9	0	0
6.0	dry	3	0	0
6.0	wet	10	0	0

CONCLUSION

Based on the results of this study, potting soil can be sterilized through the use of a microwave oven. Seedling damping-off can be controlled by microwave treatment of the potting soil for at least 2 minutes in a 1200 watt microwave oven operating with a frequency of 2450 MHz.

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USING VIRUSES TO EXAMINE SOIL TREATMENT OF SEPTIC TANK EFFLUENT

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ABSTRACT

Viral contamination of drinking water supplies due to inadequate renovation of septic tank effluent (STE) is a public health concern. The purpose of this paper is to illustrate the use of a bacteriophage to evaluate virus movement in a soil treatment system. Viruses – MS2 bacteriophage – were injected into a wastewater treatment system with soil absorption trenches and drainage tiles, and the drain tile effluent was collected and assayed for the phage. The virus suspension was assayed and a measured amount of STE and virus suspension was pumped into the system allowing for calculation of the influent virus titer. Results of the virus assays showed that the wastewater treatment system generally achieves a 99.0 (2 log) to 99.9% (3 log) reduction in the concentration of viable bacteriophage after moving through one meter of silt loam soil. This paper illustrates the procedures to utilize and assay for bacteriophage in the harsh environment of a working onsite wastewater treatment system.

INTRODUCTION

Onsite wastewater treatment is used by 42% (approximately 1 million people) of Arkansas households (Ark. Statistical Abstract, 1986). Many of the households using individual wastewater treatment systems are located in East Arkansas. This region, as well as other similar regions of the United States, generally has extremely poor soils for onsite wastewater treatment and disposal. Soils vary from expansive, non-permeable clays to fine-grained silty soils. The topography is level (except for the loess ridges) and presents extremely poor drainage. Seasonal water tables rise to the surface or above during the rainy season of the year further hampering wastewater drainage.

The main source of groundwater contamination in noncommunity and individual water systems is overflow or seepage of sewage from septic systems or cesspools, chemical contamination, and surface runoff (Craun, 1985). Craun (1985) also reports that 51% of all waterborne outbreaks and 40% of all waterborne illnesses resulted from contaminated (untreated or inadequately disinfected) groundwater supplies between 1971 and 1982 in the United States.

Clearly, as seen in Craun's study, groundwater contamination is a problem in the United States and includes contamination from septic systems. Since household sewage can contain viruses, the importance of monitoring and tracing virus movement through soil and in aquifers becomes apparent. Vaughn *et al.* (1983) recovered virus particles from a subsurface wastewater disposal system at distances of 67.05 m and from aquifer depths of 18 m. The presence of viruses at these distances further stresses the importance of finding efficient and acceptable virus models to test the effectiveness of sewage treatment systems.

Yates *et al.* (1985) demonstrated that the MS2 bacteriophage has inactivation rates equal to or slower than those of poliovirus 1 and echovirus1 in most of the samples they tested for viruses. Powelson *et al.* (1990) used the MS2 bacteriophage for a test of virus transport and survival in saturated and unsaturated flow. Therefore, the MS2 phage has been shown to be an effective model and may be used for virus studies of sewage treatment systems.

The purpose of this study was to use the MS2 phage to examine virus treatment in a tile-drained onsite wastewater treatment system. This paper describes the procedures used and the modifications made to assay treated and untreated residential sewage samples.

MATERIALS AND METHODS

VIRUS

The MS2 bacteriophage was used to evaluate virus movement in a soil treatment system. The MS2 bacteriophage was catalog number 15598-B1 and was grown in *Escherichia coli* (catalog number 15597) from American Type Culture Collection (ATCC, 1990).

The MS2 phage was used in this study for several reasons. First, coliphage is relatively safe compared to poliovirus, hepatitus, or other human-infecting viruses. Second, the coliphage assay can be performed in a relatively simple bacteriological laboratory. Third, the coliform host is simple to culture and maintain in the laboratory. Finally, the MS2 bacteriophage assay technique was developed in the EPA laboratories in Cincinnati, Ohio, and is an acceptable technique for virus studies.

HOST AND VIRUS PREPARATION

American Type Culture Collection (ATCC, 1990) gives the following directions for rehydrating freeze-dried cultures of bacteria: 1) pipette 0.5 ml of appropriate broth into the vial and mix well, 2) transfer contents to a sterile test tube containing 5.0 ml of the recommended broth, 3) incubate the mixture at 37°C for a few days (2-3 days), and 4) remove the culture and store at 5°C or lower.

To recover a bacteriophage from a freeze-dried culture, American Type Culture Collection (ATCC, 1990) gives these directions: 1) prepare an actively growing broth culture of the host before opening phage specimen, 2) rehydrate the specimen aseptically with 0.5 ml of appropriate broth and mix well, 3) use 0.1 ml of this mixture for preparation of a new high-titer phage suspension, and 4) store the remaining mixture in a sterile screw-capped vial at 2-10°C.

ASSAY TECHNIQUES

The bacteriophage assay and stock suspension procedures followed the methods outlined by Berman (1988). A bacteriophage stock suspension was prepared prior to the viral assay. This method involved pipeting 0.1 ml of the rehydrated phage suspension and 0.1 ml of a Tryptone Yeast Extract (TYE) broth culture of *E. coli* to 3.0 ml warm top agar (45°C). The mixture was gently mixed and poured evenly over a previously prepared and solidified bottom agar layer. Approximately five petri dishes were prepared this way and allowed to solidify. The dishes were inverted and incubated overnight at 37°C. A sterile, rubber spatula was used to scrape the top and bottom layers into a large, sterile beaker. Enough TYE broth was added to the agar layers to make an 80 ml suspension, and 0.4 g of EDTA and 0.52 g of lysozyme were added to the mixture. The mixture was then incubated at room temperature for two hours with continuous mixing. After overnight incubation, the mixture was centrifuged at 3000 x g for 15 minutes, and the supernatant was removed, divided into aliquots, and stored at 4°C.

Once the phage stock was prepared for the assay, and a TYE broth culture of the host was incubated (about 18 hours) the night before the assay, then the bacteriophage assay could begin using the methods

described below. This method consisted of inoculating a sample with *E. coli* host in an agar suspension in the proportion of 3.0 ml agar, 0.5 to 1.0 ml sample, and 0.1 to 0.2 ml bacterial host per tube. This warm (45°C) suspension was spread evenly over a petri dish (100 x 15 mm) containing a solidified bottom agar layer. The dishes were incubated overnight at 37°C, and the plaques were enumerated immediately after incubation. Serial 10-fold dilutions from 10^{-1} to 10^{-4} were assayed.

ASSAY MODIFICATION

The freeze-dried bacterial culture was rehydrated according to ATCC 1990) directions except for the incubation time. Assay modifications were made because the suggested incubation times proved time and time again to be unsatisfactory for producing lysis in our laboratory. Prior to the field work, we attempted to assay a sample of known virus concentration and repeatedly produced no plaques. The incubation times were modified with the belief that during the prolonged incubation times the host reverted to characteristics not conducive to MS2 phage growth. Therefore, we substantially reduced the incubation times from 2-3 days to 17 hrs for rehydrating the bacterial host and from 18 hrs to 4 hrs for prepared TYE broth culture of *E. coli* for the assay procedures.

RECOVERY EFFICIENCY METHOD

Before experimenting with bacteriophage in the field, a laboratory study was conducted to determine virus recovery efficiencies from septic tank effluent (STE) and from treated STE. MS2 bacteriophage was suspended in salt diluent made according to Berman (1988). STE was filtered through 15.2 cm of coarse filter sand, and the MS2 phage was added to the treated STE. Bacteriophage was also added to untreated STE. A 0.1 ml volume of the phage suspension was added to 100 ml each of filtered and untreated STE. The STE and phage mixture was agitated gently for approximately 3 hrs to allow the mixture to equilibrate and to let the phage adsorb to any particles suspended in the STE and filtered STE. The MS2 bacteriophage suspension, raw STE, and filtered STE were assayed for bacteriophage and recovery efficiencies were calculated using the following equation:

$$\text{recovery efficiency (\%)} = \frac{\text{measured effluent titer}}{\text{phage suspension titer}} \times 100$$

The phage suspension titer, measured STE titer, and measured filtered STE titer (PFU/ml) equaled 2.5×10^{11}, 1.2×10^{11}, and 2.0×10^{11}, respectively. Therefore, the recovery efficiency from the untreated STE equaled 48% and from the filtered STE equaled 80%.

THE STANFORD SYSTEM

In the Stanford System, the wastewater is pumped from the dose tank into the soil absorption beds. The beds are 60 cm wide and 38 cm deep and receive the septic tank effluent through 0.48 cm orifi in 3.8 cm nominal diameter schedule 40 pvc pipe. The effluent is distributed evenly over the beds by maintaining approximately 60 cm of head. The effluent delivery is by a typical low-pressure distribution system (Uebler, 1982; Hargett, 1984; and Stewart and Reneau, 1988). Figure 1 is a plan view of the treatment system. Beside and between the absorption beds are tile drain trenches. The drain trenches and the absorption beds are separated by 100 cm of undisturbed soil. The tile trenches are approximately 13 cm wide and 116 cm deep. Hancor "Turflow" slotted drain pipe was placed 10 cm from the trench bottom. The bottom of the drain trench corresponds to the top of a fragipan. Figure 2 illustrates the relative positions of the absorption beds and drainage tiles. The tile drains discharge into a sump where each tile is sampled for physical, chemical, and bacteriological analyses.

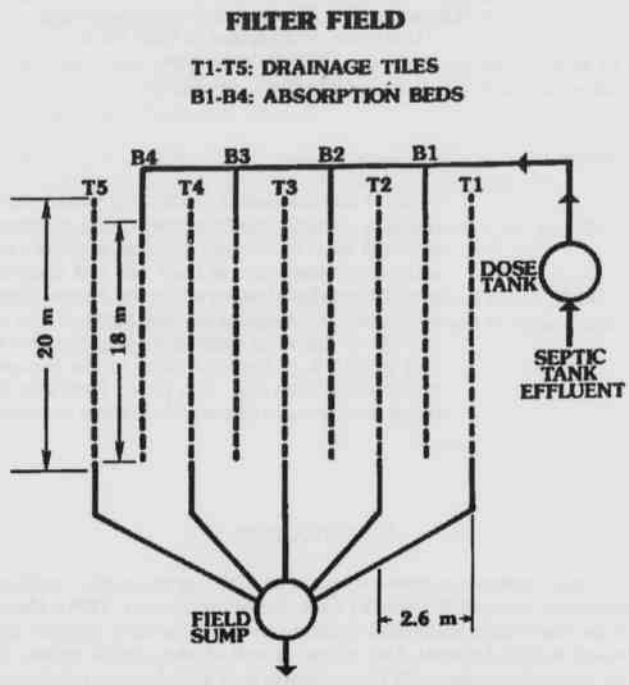

Figure 1. Plan View of Wastewater Treatment System.

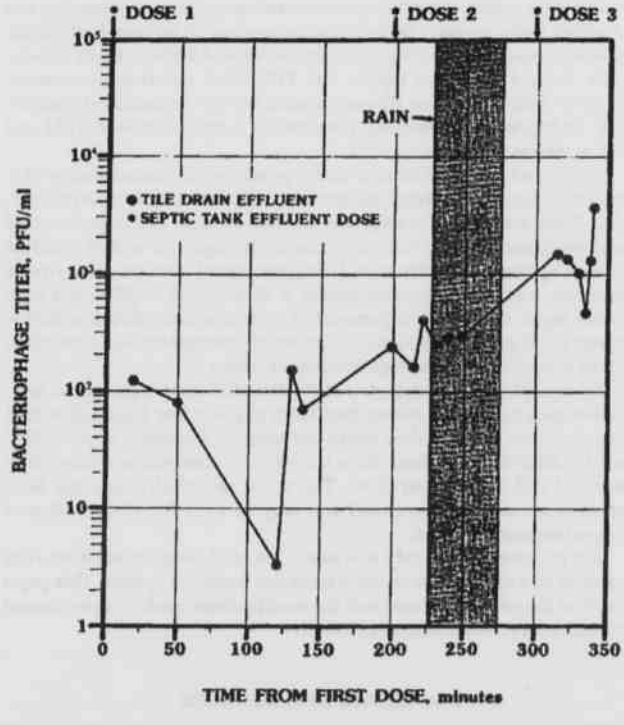

Figure 2. Typical Cross-Section Through Soil Absorption and Drainage Tiles.

FIELD STUDY

MS2 bacteriophage were introduced into the wastewater treatment system by pumping them into the pressurized distribution system. The phage suspension was prevented from flowing back into the dosing tank by means of a check valve in the distribution system. The virus was injected into the system at an existing Y-strainer downstream from the dosing pump and check valve. The final concentration of each dose was calculated as follows:

$$\text{Virus conc. of dose (PFU/ml)} = \frac{\text{virus concentration in suspension (PFU/ml)} * \text{vol. of suspension (ml)}}{\text{vol. of suspension (ml.)} + \text{vol. of dose (ml)}}$$

The virus titer in the suspension, volume of virus suspension, and volume of STE does were 3.9×10^8 (PFU/ml), 25 ml, 60 liters, respectively. Therefore, the final virus concentration of each dose was 1.6×10^5 PFU/ml. The system was dosed with STE and viruses at times 0, 168 minutes, and 279 minutes. Again, each dose contained 25 ml phage suspension and 60 liters STE.

The tile drain samples were taken consecutively from the outlets as soon as flow began to drain and were taken until the flow rate returned to a drip. Tile drain samples were collected as grab samples by placing 250 ml sample cups under each tile outlet pipe to the sump.

VIRAL ASSAYS

A total of 115 samples was collected from each of five tile outlets over a period of 343 minutes. Each tile sample was assayed using Berman's (1988) procedures without dilution and to dilutions of 10^{-1} and 10^{-2}. The plaques were counted immediately after overnight incubation at 37°C. The mean titer of the five tiles was calculated for each sample.

RESULTS

Figure 3 represents the MS2 virus concentrations (PFU/ml) collected after each effluent dose, and they are shown as the log mean concentration of viruses across the five drainage tiles. A hard rain fell from 209 minutes to 259 minutes. The assay data showed a slight increase in MS2 virus titer with each subsequent dose and after the rain. The mean average MS2 concentration for samples collected after dose 1 and before dose 2 equaled 8.1×10^1 PFU/ml. The average concentration after dose 2 but before dose 3 equaled 2.4×10^2 PFU/ml and after dose 3 equaled 1.3×10^3 PFU/ml. The system achieved a 99.9% (3-log) reduction for 35% of the samples, and a 99% (2 log) reduction or greater for 94% of the samples. Percent reduction in virus titer is calculated by the following algorithm:

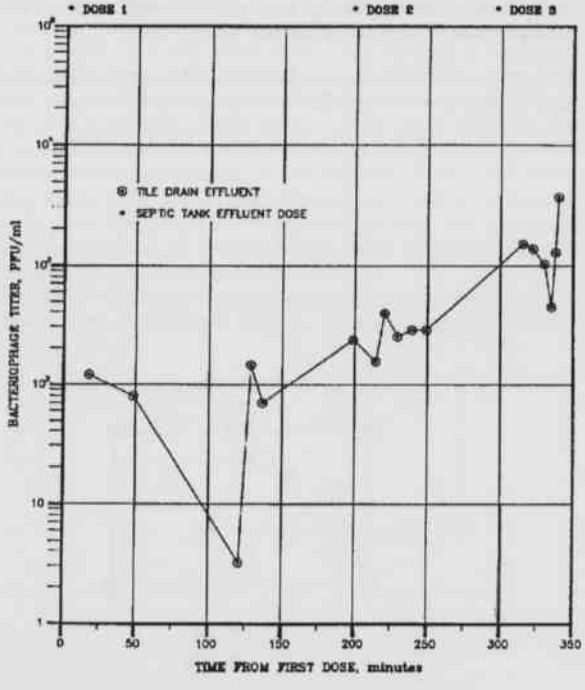

Figure 3. MS2 Virus Titer Per Sample For Each Sampling Time.

$$\text{percent reduction} = (100)\ \frac{\text{virus titer in STE(PFU/ml)} - \text{virus titer in tile effluent (PFU) ml}}{\text{virus titer in STE}}$$

Table 1 shows the numerical values of mean virus titer over the course of the sampling program.

Table 1. Effluent Virus Titer

TIME FROM FIRST DOSE, MINUTES	MEAN VIRUS TITER IN EFFLUENT SAMPLES PFU/ml
18	1.2×10^2
49	7.7×10^1
121	3.0×10^0
130	1.4×10^2
138	6.4×10^1
200	2.1×10^2
215	1.4×10^2
221	3.5×10^2
230	2.2×10^2
240	2.5×10^2
250	2.5×10^2
317	1.3×10^3
322	1.2×10^3
330	8.9×10^2
335	3.7×10^2
338	1.1×10^3
343	3.2×10^3

DISCUSSION

As seen in Fig. 3, the MS2 virus concentration showed a slight increase with each subsequent dose and with rain. We believe that this general increase may be due to saturation of the system. The system was dosed with 60 L of septic tank effluent (STE) at zero minutes, again at 168 minutes, and again at 279 minutes for a total of 180 L. Powelson *et al.* (1990) demonstrated that the MS2 phage showed little adsorption or inactivation in the saturated condition compared with the unsaturated condition. We suggest that the Stanford system achieved a saturated condition; thus the system's filtration capabilities were reduced to a lower level, and more MS2 phage particles escaped with the STE.

The Stanford Onsite Wastewater Treatment system is capable of a 99.0% (2 log) reduction in virus titer and has shown up to a 99.9% (3 log) reduction in virus titer. The EPA regards a 99.99% (4 log) reduction in virus concentration as acceptable treatment for potable water treatment systems (Cave, 1990).

Rose and DuPont (1988) report that normal enteric virus concentrations in the average household are in the range of 10^2 to 10^3 PFU/L (0.1 to 1.0 PFU/ml). We injected a virus concentration (1.6×10^5 PFU/ml) that is two to three logs greater than the average concentration. Therefore, an average household virus concentration could be effectively reduced to 10^{-3} - 10^{-2} PFU/ml(3-log) with the Stanford system.

Other researchers have used the MS2 bacteriophage effectively for virus removal from septic tank effluent and suggest that the MS2 phage may be acceptable for testing soil treatment systems filtering capabilities (Yates, 1985; Powelson *et al.* 1990). Although, Goyal and Gerba (1979) concluded that no one virus may serve as the ultimate model for determining virus adsorption to soils due to a large degree of variability both between and within strains of enteroviruses. Their data show that the MS2 phage had equal to or lower percent adsorption than the poliovirus1 and echovirus 7 strains in most soil types.

CONCLUSIONS

1. The typical viral assay may have to be modified to suit the laboratory in which the assay will take place. In our case, the incubation times had to be reduced for lysis to occur on the plates.
2. Before performing a field experiment with MS2 phage, a recovery efficiency experiment should be conducted in the laboratory. This experiment will allow the researcher to determine what percentage of virus particles will adsorb in the septic tank effluent before filtration ever begins. In other words, the experiment will determine what percent of virus particles will be lost simply by introducing them to the sewage.
3. This active, tile-drained system is capable of a 99.0% (2 log) to 99.9% (3 log) removal or inactivation of MS2 phage.

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PROPERTIES OF RUTHENIUM OXIDE COATINGS

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ABSTRACT

Ruthenium oxide coatings have been deposited on titanium substrates using a flood coating process. These films were heat treated for varying times and temperatures. The resulting films subsequently were characterized by performing resistivity and SEM analyses. Resistivity of the ruthenium oxide coating was found to be extremely dependent upon the firing temperature. Effect of the process conditions and formulations of the coatings on the morphology with respect to their electrical characteristics is presented. Capacitors were fabricated using plates coated with ruthenium oxide coatings. Capacitance versus heat treatment temperatures are discussed and at one firing temperature (480°C), the capacitance was 50 times the control capacitor value.

INTRODUCTION

TRANSITION METAL OXIDES

Among the oxides of the transition metals, only TiO (Morin, 1956), RuO_2 and IrO_2 (Ryden et al., 1968) are known to be metallic conductors at ambient temperature. The metal-metal distance and the radius of the cation in these oxides are such that overlap of the inner d orbitals between ruthenium and oxygen is possible, and the d electrons in the d bands are responsible for the metallic conduction (Morin, 1956; Marcus, 1968; Rogers, *et al.*, 1969; Trasatti and Buzzanca, 1971; Boman, 1970; Baur, 1956; Avdeev, *et al.*, 1971; Ryden, *et al.*, 1970; Schaefer, *et al.*, 1963; Erenburg, *et al.*, 1972; Chu, 1970; and Galizzioli, 1975).

Ruthenium oxide, in comparison with other metallic oxides, presents the advantage of preparation at relatively low temperatures. It can be deposited easily as a film a few micrometers thick on an inert metallic support. The low temperature of preparation makes the oxidation of the support and possible interdiffusion at the solid interface negligible.

The d-electron configuration for the cations, if the oxides are considered to be fully ionic, is $4d^4$ for ruthenium (Ryden *et al.*, 1968). The resistivity, at room temperature, of intrinsic RuO_2 is 3.5×10^{-5} ohm x cm (Ryden and Lawson, 1970). This resistivity value will cause little ohmic resistance in a film of one to two micrometers thick, but the value does suggest that the films are semiconductors which are reasonably assumed to be n-type (Kuhn and Mortimer, 1973).

In the rutile structure, the metal atoms are placed at the cell center and the body center of the crystal (Fig. 1). The metal atoms are coordinated very nearly octahedrally by oxygen, with one axis of the octahedron being 2% shorter than the others. Four of the six Ru-O distances are 1.984 ± .006 Å and the other two are 1.942 ± .010 Å. The shortest Ru-Ru distance is 3.107 Å which precludes any significant metal-metal interaction.

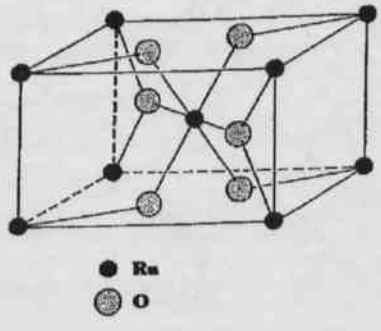

Figure 1. Unit cell in intrinsic rutile. Small black balls are ruthenium atoms and the chocked larger balls are oxygen atoms

Rare-earth oxide coated titanium substrates are widely used in the chlor-alkali industry for the production of chlorine in saturated acidified brine at 70°C (Arikado *et al.*, 1977; O'Grady *et al.*, 1974; De Nora, 1970; De Nora, 1971; Beer, 1968; and Kuhn and Mortimer, 1972). This electrochemical process is one of the harshest environments to which an electrode can be subjected. The ruthenium oxide layer on the surface of a titanium electrode inhibits passivation of the titanium and acts as an excellent electronic conductor at the electrode side of the electrode-solution interface. Additionally, rare-earth composites, and in particular RuO_2, show exceptional mechanical stability.

Numerous oxide coatings for titanium have been developed. The vast majority are based on RuO_2 with the addition of various other rutile oxides. The basic coating is formed from a solution of $RuCl_3$, HCl, butanol, and n-butyl titanate $Ti(OBu)_4$ in various proportions. Acid-cleaned (HCl, 6.0M, one minute) titanium substrates are dipped into this solution and oven-fried at 400-500°C for 5 to 30 minutes depending on the specific coating desired. During the pyrolyzing of the coating mixture, the surface of the titanium also is pyrolyzed to a mixed $TiO\text{-}TiO_2$. This compound is essentially rutile in nature and forms a diffuse interface with the coating material.

EXPERIMENTAL

RUTHENIUM OXIDE COATING PROCEDURES

Titanium squares (one inch x one inch x .035 inch) were completely liquid coated on one side only (flood coated) with solutions of $RuCl_3$, HCl, butanol, and n-butyl titanate $Ti(OBu)_4$ in various proportions. After liquid coating of the titanium squares, the squares were air dried for twenty-four hours. The air dried squares then were fired in the temperature range of 475 - 495°C for time periods ranging from 5 - 20 minutes in a Lindberg Type 51333 oven equipped with a Lindberg Eurotherm Controller/Programmer Type 813. Firing temperature was found to be very critical in guaranteeing an integral and mechanically stable coating on the titanium squares. The optimum firing time was found to be eight minutes. The final optimum coating formulation mixture was: 3.0 gms of ruthenium metal as $RuCl_3 \times 3H_2O$, 3.0 ml of concentrated HCl, 46.0 ml of butanol, and 22.0 gms of n-butyl titanate. Additional coats were applied by repeating the coating, air drying, and firing procedure. Three coats were applied to all titanium squares that were measured for resistance and capacitance.

All four probe resistivity measurements used a Keithley Model 224

Programmable Current Source, a Keithley Model 617 Programmable Electrometer, and a four probe head from Alessi. The four probe head was a spring loaded constant pressure head mounted in a Cambridge Thermionic Corporation pressure swager yoke. After final coating and firing, two titanium squares were placed in a home-built Plexiglas fixture. Polyethylene film (2 mil) was used as the dielectric whereupon the two plates were forced together with four screws in the fixture. Access holes were drilled in the fixture to allow connection for capacitance measurements. Capacitance measurements used a General Radio Model 1200 Capacitance Bridge operated at 1.0 kHz. All SEMs were made using a Cambridge Instruments Steroscan 600.

RESULTS AND DISCUSSION

The firing temperature has a profound affect upon the ruthenium oxide morphology as shown by the SEM's in Figs. 3-6. The final appearance was dark violet or purple to black with a slight metallic luster. As can be seen, the coatings have the appearance of a mud-cracked, dried out lake bottom. The unique properties of the ruthenium oxide coatings can be attributed to both its low electrical resistivity, as well as the apparent increased surface area. No stoichiometric analyses were performed to determine the exact Ru/O ratios for the coats that were formed. The morphology (in going from 475°C to 490°C) clearly demonstrates that the individual oxide plates were diminishing in average size, that is, the surface became more cracked. However, whether the cracking depth varied concomitantly was not ascertained. The changes in morphology with increasing temperature followed the dramatic drop in resistivity as shown in Fig. 7. The control line is the resistivity value measured on a cleaned titanium square and shown in Fig. 2. All data points are the average of six resistivity values that were measured at random locations on the coated squares. Since no determinations were made of composition or purity, the

Figure 2. SEMof a cleaned titanium square at 200 x.

resistivity changes may not be reflective of heating effects, but may indicate sample impurities (for example, Cl^-) or structural defects. Additional resistivity measurements are in progress as a function of not only firing temperature, but firing time to determine the optimum parameter to minimize coating resistivity.

Figure 3. Three coated surface fired at 475°C for eight minutes at 200 x

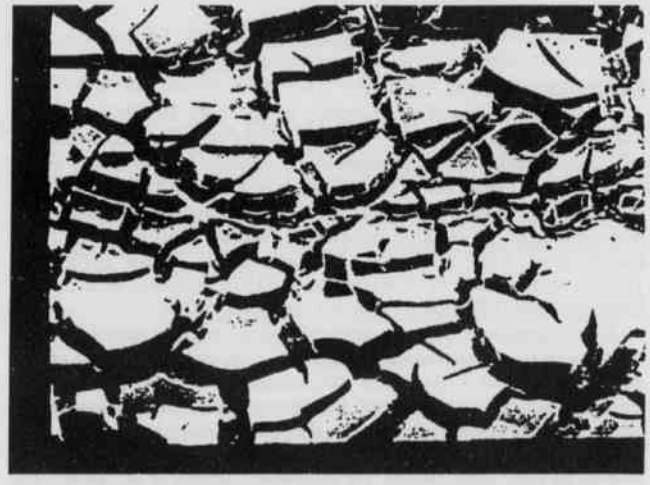

Figure 4. Three coated surface fired at 480°C for eight minutes at 200 x.

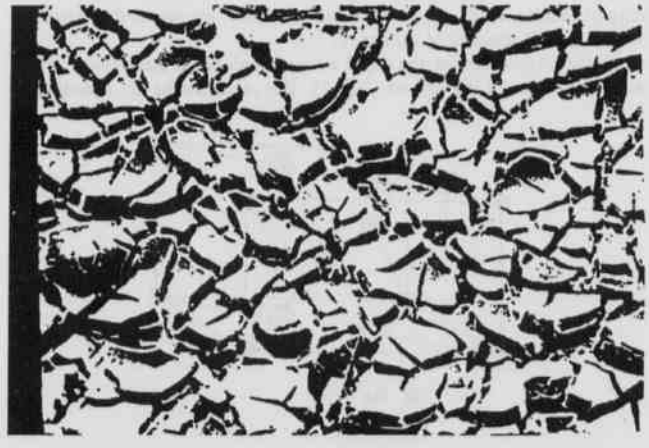

Figure 5. Three coated surface fired at 485°C for eight minutes at 200 x.

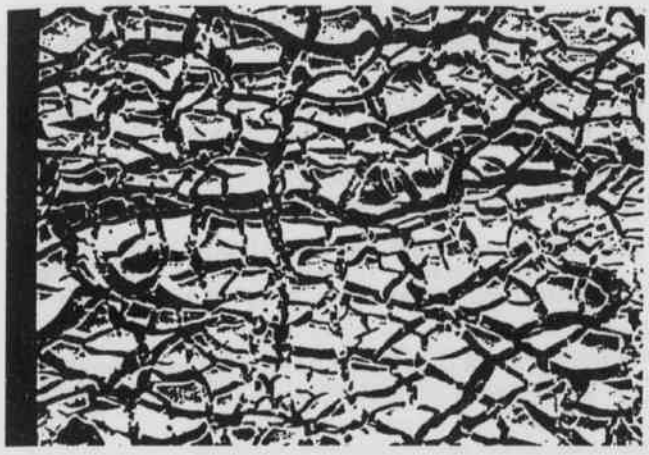

Figure 6. Three coated surface fired at 490°C for eight minutes at 200 x.

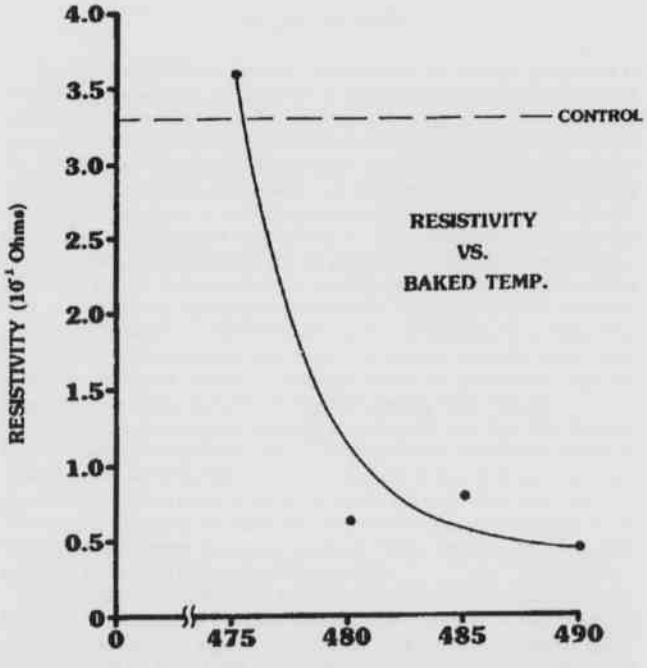

Figure 7. Resistivity versus firing temperature for the three coated surfaces.

Capacitance data are presented in Table 1. The data are suspect since the fixture used to sandwich the polyethylene film between the two coated squares was not designed to insure that the two plates were held together by the same force to cause the same interplate distance. However, the results (even though preliminary) do indicate that at approximately 480°C, the quasi-capacitor had a marked increase in measured capacitance. Further capacitance measurements are being readied using a constant pressure fixture and also variable polyethylene thicknesses (1 mil, 2 mil, and 3 mil). Substitution of manganese, iridium, and titanium in the coating mixtures are proposed in future studies.

Table 1

Firing Temperature (°C)	Capacitance (nF)
470	.1
475	.15
480	5
485	.2
490	.1

CONCLUSIONS

Resistivity of ruthenium oxide coatings were found to be extremely dependant upon the firing temperature and firing time. Ruthenium coatings show promise as the conductor plates in capacitors.

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DOUBLE TUNED COSINE COIL FOR NMR IMAGING/SPECTROSCOPY

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ABSTRACT

The fabrication of a cosine coil having unevenly distributed struts is detailed. Placing the struts in such a manner enables a standing wave at the desired frequency and, hence, only one resonance frequency is obtained. This study details the fabrication of a cosine coil tuned to the Li-7 frequency (77.76 MHz) and then double-tuned to the H-1 frequency (200.1 MHz) when operated at 4.7 Tesla. Double-tuning is attained by placing an LC trap in series with a capacitor used to single-tune the coil. Also, a method is suggested by which a cosine coil can be broadbanded in the lower frequency range simply by replacing a fixed capacitor.

INTRODUCTION

One goal of NMRwith *in vivo* subjects such as humans or animals is to extract biochemical information on phosphorous metabolites, carbon metabolites, or sodium distribution from local regions in the body. This generally is accomplished by obtaining a proton image and then performing ^{31}P, ^{13}C, or ^{23}Na NMR spectroscopy (or chemical shift imaging) on a localized region. When quantitative information is needed, it is of utmost importance that there is no ambiguity as to the origin of these signals. Since these nuclei are not as sensitive as ^{1}H, it makes no sense to image phosphorous and then localize for the phosphorous metabolite spectra in a particular region. It is possible to obtain a proton image of the subject first, and then very carefully reposition the subject in exactly the same position as before in another RF-coil tuned to a different frequency. This is exceedingly cumbersome and, regardless of how carefully such a procedure is employed, proper localization cannot be guaranteed, with the danger of data being contaminated by surrounding tissue signals.

Hence, it is very highly desirable to use an RF-coil that can resonate at more than one frequency. One of the frequencies that almost always is desired, when working with biological subjects, is the ^{1}H frequency, since good morphological images can be obtained in a very short time. Once an ^{1}H image is obtained, the same RF-coil should have the capability to be returned to a different frequency (such as ^{31}P) to obtain a chemical shift image or a localized spectrum of this nucleus.

One of the first body coils that was tunable to two frequencies was designed by Joseph and Fishman (1985), who were able to tune a saddle coil that contained an angular distribution of wires on a Plexiglas cylinder, to 59.1 MHz for ^{1}H and 55.6 MHz for ^{19}F. Frequency switching and matching at these frequencies was accomplished by external capacitors and varying cable lengths. Although this coil was able to double-tune between two frequencies separated by 4 MHz, considerable difficulty arises when trying to double-tune by this method to frequencies separated by greater than 10 MHz.

Schnall *et al.*, (1985a) and Schnall *et al.*, (1985b) were able to double-tune a surface coil by attaching an LC trap in series with the tuning capacitor that was used for single-tuning the surface coil. Excellent isolation is achieved between the high and the low frequencies in such an arrangement. Employing such a method to RF-coils for whole body imaging/spectroscopy has been rather slow and is still in the research stage (Isaac *et al.*, 1990.)

Birdcage coils are the most popular coils for volume imaging since they produce a highly homogeneous B_1 field (Hayes et al., 1985). The birdcage is an extension of the principle used in a saddle coil where a perfectly homogeneous transverse magnetic field in an infinitely long cylinder can be obtained by a surface current running along the path of the cylinder. This current is proportional to cosø, where ø is the azimuthal angle (Hoult and Richards, 1976). Whereas in saddle coils the current carrying wires along the length of the cylinder are spaced equally at 60°, 120°, 240°, and 300° to assume a sinusoidal distribution, in birdcage coils many parallel conductors (more than four) are placed on the cylinder and a sinusoidal distribution is imposed on these conductors by distributed capacitance. Multiple tuning such coils is quite a formidable task since these parallel conductors exhibit several modes of resonance.

Recently, it was shown that a cosine distribution could be obtained by placing discrete parallel conductors nonuniformly around the cylinder (Bollinger *et al.*, 1988). Such a system was shown to easily double-tune using the LC trap method as there is only one frequency at which it resonantes when it is singly tuned, unlike the birdcage coil which exhibits several modes of resonance (Bollinger *et al.*, 1988). The ease with which such a coil can be double-tuned is one of the attractive features of this coil. A step-by-step method of constructing such a coil is described below. The results for a coil that was double-tuned to 200 MHz for ^{1}H and 77 MHz for ^{7}Li are described.

EXPERIMENTAL

SINGLE-TUNED COSINE COIL

Fig. 1 shows a schematic drawing of a typical cosine coil. Two groups of conductors (referred to as struts) are placed on a Plexiglas

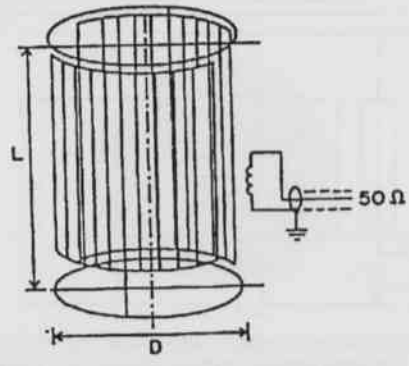

Figure 1. A typical cosine coil along with the end rings.

cylinder in a symmetrical manner opposite to each other. The way these groups of conductors are placed is shown in Fig. 2. The following steps can be followed in order to position the struts:

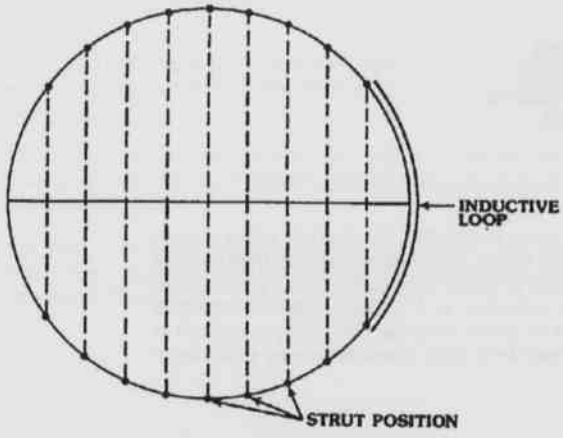

Figure 2. Cross section of cosine coil showing the points where the struts are placed. The spacing between the struts and the number of struts may be varied depending upon the desired inductance.

a) Draw a circle representing the cross section of the Plexiglass cylinder.
b) Decide on the number of struts desired and divide the diameter of this circle into that many equal segments.
c) Project these points from the diameter onto the circumference of the circle.
d) Place the group struts on the cylinder at these positions.
e) Connect each group of struts by an arc at each end of the struts.
f) Connect the center strut in each group to two end rings placed symmetrically above and below the struts. These act as the current carrying loops.

One of the gaps between the two groups of struts should be chosen to inductively feed such a coil. The inductive loop for such a coupling should have a width equal to the separation of the two groups of conductors and the length should be equal to the length of the struts to achieve maximum coupling between the loop and the coil. The inductive loop should be connected in series with a variable capacitor C_m (used for matching to the coil), the other end of which is connected to the center conductor of the transmission line as shown in Fig. 3. The other end of the loop is connected to the ground (shield of the transmission line).

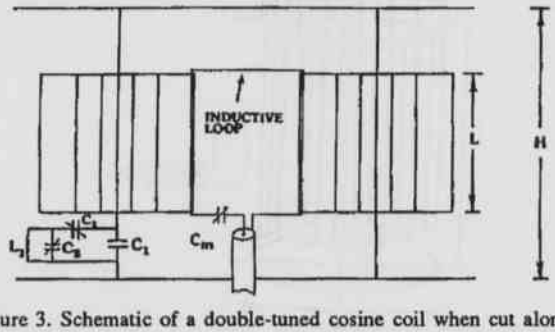

Figure 3. Schematic of a double-tuned cosine coil when cut along the length of the cylinder, showing different features and components when inductively fed.

Once the inductive feed is put into place, the following steps are followed to single-tune the cosine coil.

a) Cut the connection between one of the groups of struts and the outside ring.
b) Place a reasonable value fixed capacitance (C_1) between these two points.
c) Connect the transmission line to a network analyzer such as Wiltron model 6407 RF analyzer and look for the resonance frequency of the coil.
d) Determine the inductance of the coil using the equation $\vartheta = 1/2\pi\sqrt{L_s C_1}$) (this only will be an approximate inductance, but a good one to start with), where ϑ is the frequency of resonance, and Ls is the inductance of the cosine coil.
e) If the coil resonance is above or below the desired frequency, change the capacitor value to resonate the coil at the desired frequency since the inductance is known from the above formula.
f) Place the new capacitance (new C_1) calculated from part (e) and repeat part (c). The resonance should be very close to the desired frequency.
g) Place a variable capacitor (C_2) in parallel to this fixed capacitor which will allow fine tuning to the exact frequency, and will provide adjustment for the difference in tuning on the bench compared to in the magnet.
h) Use the capacitor C_m that is in series with the inductance loop to match the coil to 50 ohms.

A slight improvement in field homogeneity may be obtained if the fixed capacitor is distributed by placing another capacitor symmetrically across between the other group of conductors and the outer ring. Electrically, this point is in series with the first capacitor.

DOUBLE-TUNING THE COSINE COIL

When designing a double-tuned cosine coil, the coil should first be single-tuned for the lower frequency as described in the above section. Double-tuning to a higher frequency is achieved by placing a trap in series with the variable capacitor C_2 as seen in Fig. 3. The trap consists of a variable capacitor C_3 in parallel with an inductor (L_1). Appropriate turns on the inductor are determined by trial and error. Capacitor C_2 has very little reactance at higher frequencies compared to the trap circuit or the coil whereas at low frequencies C_2 is the dominant term in the reactance, since the trap looks more like an inductor, thus passing low frequencies (Schnall *et al.*, 1985a). The picture of a inductively fed cosine coil double-tuned to ^1H-^7Li is shown in Fig. 4.

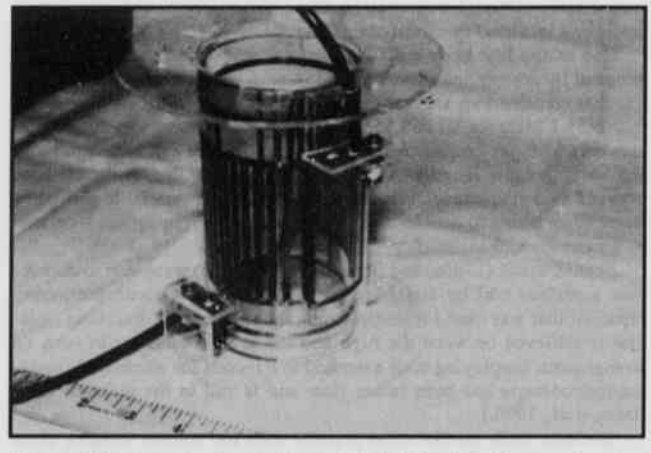

Figure 4. Photograph of an inductively fed ^1H-^7Li double-tuned cosine coil.

These coils also can be double-tuned by capacitive coupling by using the balanced matched method (Chang *et al.*, 1987). An equivalent circuit of such an arrangement is shown in Fig. 5. The capacitors C_4 and C_5 provide a balanced matching at both frequencies and also reduce the dielectric losses when the coil is loaded. The picture of a capacitively fed cosine coil double-tuned to ^1H-^{13}C is shown in Fig. 6.

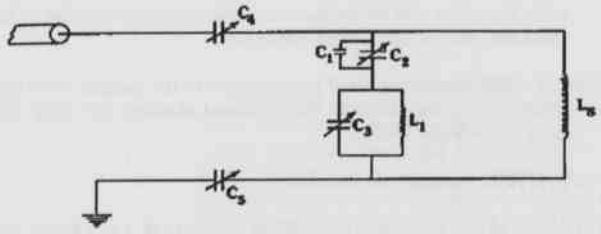

Figure 5. Schematic of a balanced matched capacitively driven, doubled-tuned cosine coil. (C_4 and C_5 are the matching capacitors).

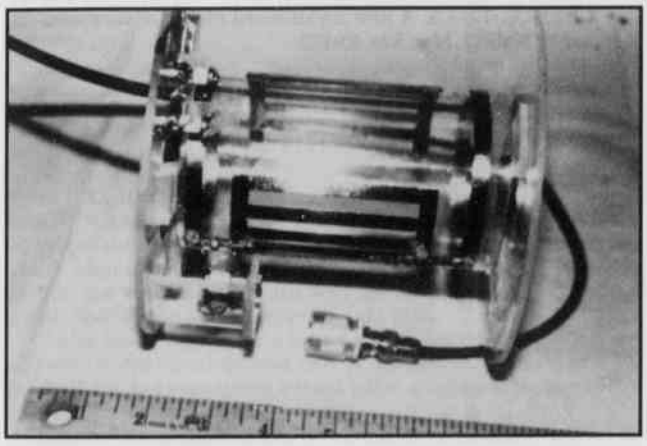

Figure 6. Photograph of a double-tune (^1H-^{13}C), balanced matched, capacitively fed cosine coil.

^1H-^7Li COIL

A double-tuned cosine coil was fabricated using 0.6 cm wide copper tape according to the above procedures to tune for ^7Li at 77.75 MHz and ^1H at 200.1 MHz. The length of the coil was 7.5 cm and the inside diameter was 7.0 cm. The two groups of conductors had seven struts placed one cm apart along the diameter of the cross section. The outer rings were placed at 1.9 cm on each side from the struts. A schematic of the coil, when cut along the length of the cylinder, is shown in Fig. 3. The coil was fed inductively. The value of capacitor C_1 was 24 pF. The values of the variable capacitors C_2, C_3, and C_m were 1-30 pF.

RESULTS AND DISCUSSION

A phantom containing 1.0 M LiCl solution which occupied 50% of the coil volume was used for testing the ^1H-^7Li coil. The unloaded and loaded Q values of the coil at 77.75 MHz were 220 and 90, respectively, whereas at 200.1 MHz, they were 180 and 83, respectively. The 90° pulse for ^7Li was 350 μs using 83 watts of power, whereas it was 480 μs for ^1H using 40 watts of power.

Figure 7a shows 128 x 128 axial and sagittal ^7Li images obtained from the phantom. The slice thickness on the sample was one cm and the field of view was 10 cm. The RF homogeneity is extremely good in these images. Fig. 7b shows a 128 x 128 axial ^1H image, from the same sample, using a one cm thick slice. The image shows some RF inhomogeneity. The variation in RF inhomogeneity was approximately 15%.

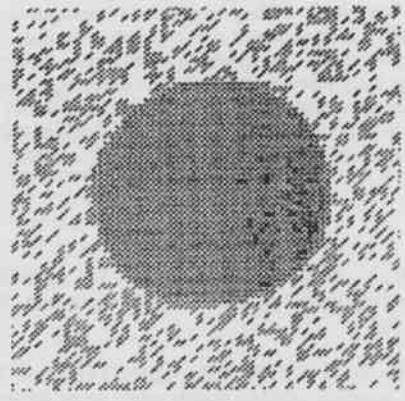

Figure 7.
(a) Axial 128 x 128 ^7Li image of a phantom containing 1M LiCl solution. (Field of view = 10 cm; slice thickness = 1 cm; scans = 4; power = 66 watts).

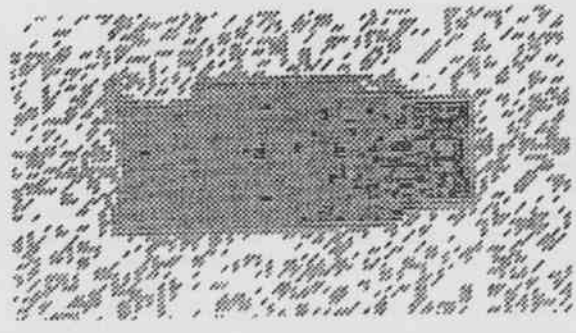

Figure 7.
(b) Sagittal 128 x 128 ^7Li image of the same phantom in (a) obtained under the same conditions.

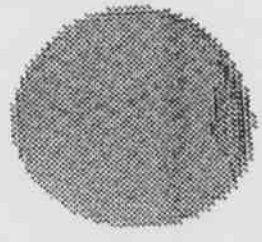

Figure 8. Axial 128 x 128 ^1H image of the same phantom used in Figure 7a obtained under the same conditions except the power used was 10 watts.

Cosine coils are relatively simple to build. Depending on the application at hand, the loss of RF homogeneity may be tolerable at the high frequency. Improvement on the RF homogeneity may be made by distributing the fixed capacitance C_1 onto the other group of conductors, as long as symmetry is maintained. Recently, a method to further improve RF homogeneity was suggested by Lowe (1990) which takes care of the slight difference in currents between the outer struts and innermost strut in the group of conductors. This method was tested only on a single-tuned coil, but also may result in improvement in homogeneity at a second higher frequency. It is observed that a length to diameter ratio of one gives a better performance compared to a 2 to 1 ratio (Lowe, 1991). Such a problem was seen when building a coil resonating at 50.3 MHz and 200.1 MHz. Double-tuning was extremely difficult when the length to diameter ratio was 1.7 and relatively easy with a ratio of one. Best results were obtained when the ratio of length to diameter was one.

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REPORTED ANIMAL RABIES IN ARKANSAS: 1982-1990

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ABSTRACT

Reported animal rabies in Arkansas is reviewed for the years 1982-1990; providing an update from 1950-1981 (Heidt, 1982). Total cases ranged from 39 in 1990 to 168 in 1986, with a mean of 123.1. Wildlife accounted for 93.4% of the total cases. A total of 16 kinds of mammals has been implicated in reported rabies (individual species of foxes and skunks have been combined). The four taxa accounting for the highest incidence are: skunks (82.6%); bats (10.1%, all seven species combined); cattle (2.8%); and dogs (1.5%). Skunks, the most prominent species, ranged from 71.8% in 1990 to 90.2% in 1987. These figures were similar to the previous ten years, with the exception of 1977-1979 when Arkansas experienced a severe skunk rabies epizootic.

INTRODUCTION

In 1982, Heidt published a comprehensive review of reported animal rabies in Arkansas, covering the years 1950-1981. In that study he pointed out that the first known case of rabies in Arkansas dated from the late 1880's when a human death was recorded in Garland County. He further reported that actual statistical data were not compiled until 1940 and that a breakdown by species was not begun until 1946.

During the 31 years covered by that review, Arkansas contributed significantly to the annual national total of reported rabies (mean of 3.4% per year), and had experienced a skunk rabies epizootic in the late 1970's (Heidt, 1982; Heidt *et al.*, 1982.).

Reported bat rabies, while recorded, was not delineated by species. In July, 1982 one of the authors (DAS) began to routinely identify bats tested by the Arkansas Department of Health; a practice still being continued. In light of the identification of bats tested, McChesney *et al.* (1983) reviewed reported bat rabies for 1982 and Heidt *et al.* (1987) reviewed reported bat rabies between 1982-1986.

The purpose of this study was to update reported animal rabies in Arkansas for the years 1982-1990, thus providing current summaries on this important disease. The number of reported rabies cases can be influenced by a number of factors including public awareness, number of animal bites, proximity to health departments, previous experience with animal rabies, and human population densities (Verts and Storm, 1966; Lewis, 1972; Carey *et al.*, 1978). Furthermore, untold numbers of animal rabies cases go undetected due to the secretive or nocturnal habits of most animals, lack of human presence in a given epizootic area, quickness of death once there is an onset of symptoms, and most rabies cases are expressed in the 'dumb' rather than 'furious' form (McLean, 1970; Kaplan and Koprowski, 1980). Reported rabies, however, is a useful tool for showing trends and epizootics.

METHODS AND MATERIALS

Data for the Arkansas portion of the study were compiled from annual data supplied by the Arkansas Department of Health (ADH). Supplementary information was obtained through several conversations with Dr. Thomas C. McChesney of the ADH. National reported rabies data were compiled from several publications of the National Centers for Disease Control (CDC, 1983, 1984, 1985, 1986, 1987, 1989).

RESULTS AND DISCUSSION

GENERAL ASPECTS

The Division of Laboratories of the Arkansas Department of Health is responsible for testing all specimens which are submitted by concerned individuals. Over the past nine years a total of 12,185 ($\bar{x}$ = 1354) specimens has been examined. Of the submitted specimens, 1076 (8.8%) have tested positive (ranging from 3.4-13.2%). This relatively low percentage is due, in part, to the submission of rodents, opossums, and raccoons. These three groups totaled 2097 specimens (16.4% of total submissions); one raccoon tested positive.

Total reported cases of rabies in Arkansas (1982-1990) ranged from a low of 39 in 1990 to a high of 168 in 1986, with a mean of 120 cases per year (Table 1, Fig. 1). This pattern continues the previous 31 year history

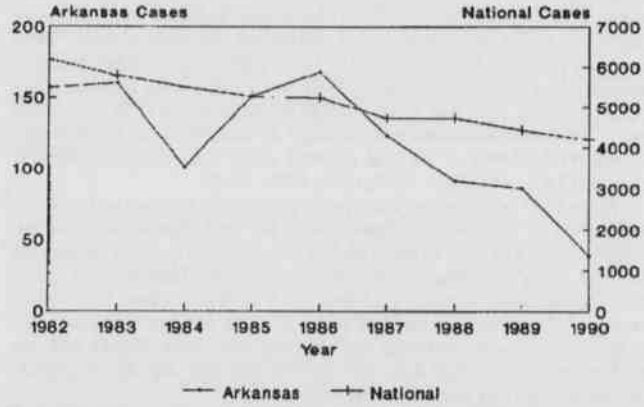

Figure 1. Total Arkansas and national reported cases of rabies: 1982-1990.

Reported Animal Rabies in Arkansas: 1982-1990

Table 1. Reported animal rabies in Arkansas: 1982-1990. Parentheses indicate percentages.

YEAR	DOG	CAT	CATTLE	HORSE	MISC. DOMESTIC	FOX	SKUNK	BAT[a]	MISC. WLDLF	TOTAL	NATIONAL	%NATIONAL
1982	4(2.5)	2(1.3)	4(2.5)			2(1.3)	126(80.3)	19(12.1)		157	6193	2.5
1983	4(2.5)	1(0.6)	7(4.4)	2(1.2)		2(1.2)	128(80.0)	16(10.0)		160	5798	2.8
1984	1(1.0)	2(2.0)	2(2.0)				80(80.0)	16(16.0)		101	5508	1.8
1985	1(0.7)	1(0.7)	4(2.6)		1(0.7)[b]		131(86.8)	13(8.6)		151	5269	2.8
1986	2(1.2)	3(1.8)	2(1.2)	2(1.2)		1(0.6)	143(85.1)	14(8.3)	1(0.6)[c]	168	5242	3.2
1987	3(2.4)	1(0.8)	4(3.3)				111(90.2)	2(1.6)	2(1.6)[d]	123	4729	2.6
1988	1(1.1)		3(3.3)	2(2.2)		1(1.1)	76(83.5)	8(8.8)		91	4724	1.9
1989	2(2.3)	1(1.2)	3(3.5)	4(4.6)			67(77.9)	9(10.5)		86	4430	1.9
1990			1(2.6)				28(71.8)	9(23.1)		39	4191	0.9
TOTAL	18(1.7)	11(1.0)	30(2.8)	10(0.9)	1(0.7)	6(0.6)	890(82.7)	106(9.8)		1076	46084	2.3

a - includes seven species b - goat c - coyote d - coyote and raccoons

of peaks and troughs (Heidt, 1982). During the previous 31 years there were seven transient and two major peaks of rabies activity. The years encompassed by the present study demonstrate one peak and two troughs; the relatively high numbers in 1982 and 1983 represent a declining plateau following the major skunk epizootic seen in 1977-79. This general cyclical pattern of transient increases and decreases followed by a major outbreak has been reported in other states (Sanderson *et al.*, 1967; Friend, 1968; Hall, 1978; Wampler and Kirkland, 1981). In Arkansas, the major peaks of activity have appeared approximately every 10 years, last occurring in 1979 (Heidt, 1982). If the general pattern holds true, another major peak of activity should occur within the next 2-3 years.

Over the past nine years, 70 of Arkansas' 75 counties have reported at least one case of rabies. On the average 39.2 counties have reported rabies each year (ranging from 23 counties in 1990 to 46 counties in 1982 and 1986).

Figure 1 compares total reported rabies in Arkansas with that in the United States. National rabies has shown a steady decline over the past nine years, while Arkansas experienced a peak in 1985-86. During the past nine years, Arkansas contributed an average of 2.3% (ranging from 0.9-3.2%) of the nation's reported rabies (Table 1); down about a percentage point from the previous 31 years.

Reported animal rabies for this study are summarized in Table 1. Sixteen different kinds of mammals (no distinction is made between individual species of skunks and foxes) have been reported with laboratory confirmed rabies. Five of these are considered domestic animals, while the other 11 are classified as wildlife. Heidt (1982) reported that domestic animal rabies predominated until 1963 when cases were approximately equal. Between 1963 and 1981, wildlife rabies averaged 84% of the total cases. This trend continued even stronger as wildlife rabies has averaged 93.4% (91.3-97.4%) of the total reported cases. Nationally, this trend is similar (CDC, 1983, 1984, 1985, 1986, 1987, 1989).

Since 1975 when proper vaccination procedures for dogs and cats was established by law, rabies in these species has been dramatically reduced. Reported rabies in each of these species averages less than 2% of the total reported rabies and appears to be rather insignificant. Bovine rabies is also rather insignificant, averaging 2.8% (1.2-4.4%) of total cases. It should be cautioned, however, that cases of rabies in cattle may go unreported due to the difficulties in obtaining and shipping specimens. Horses and one goat represent the other domestic species and they are also negligible (horses average less than 1% of the total cases).

A total of 1288 rodents and rabbits has been submitted for testing. None of these animals has tested positive and over the past 40 years only 4 rodents have tested positive in Arkansas. It is impossible to determine, however, how many of the specimens are household pets which would be very unlikely to have the disease. Nationally, rodents account for a disproportionate number of animal examinations. For example, Fishbein *et al.* (1986) reported that in 1984, rodents represented 10.1% of the 87,870 animals examined for rabies in the United States, but only 29 (0.5%) of the 5,547 positive animals were rodents and lagomorphs. Moro *et al.* examined rodent rabies in Maryland from 1981 to 1986 (a period of raccoon rabies epizootic) and found that rodents and lagomorphs comprised 1.2% of the total positive reported cases (44 cases). Of these, woodchucks accounted for 35 cases. Where rodent rabies does occur, it appears to be correlated with epizootic outbreaks of raccoon or skunk rabies (Fishbein *et al.*, 1986; Moro *et al.*, 1991). There were, however, no rodent or lagomorph cases reported in Arkansas during the skunk epizootic of 1977-79 (Heidt, 1982).

Raccoons represent one of the four major wildlife rabies vectors in the United States. Previous to the late 1970's, raccoon rabies was enzootic to the southeastern United States (McLean, 1975). In 1977, a wildlife rabies epizootic began in the mid-Atlantic region of the United States. The outbreak has been linked to raccoons translocated from the southeastern United States to augment existing populations for sport hunters (Nettles *et al.*, 1979; Smith *et al.*, 1984). The numbers of raccoon rabies cases in this area were quite dramatic as evidenced by 545 reported cases in Virginia and 732 in Maryland in 1983 and in 1984 there were 281 cases in Pennsylvania and 964 in Maryland (CDC, 1984, 1985). This epizootic points out the need for caution when transporting and releasing animals between geographic areas.

In Arkansas, raccoon rabies is virtually nonexistent and only 10 cases have been reported since 1950; the most recent case reported in 1987. Recent research with monoclonal antibodies has shown that there are a number of strains which may be specific for certain species of animals (Smith, 1989). In all probability those strains for raccoons are not found in Arkansas and the rare case of rabies in raccoons represents an isolated occurrence.

In Arkansas, foxes (both red, *Vulpes fulva*, and gray, *Urocyon cinereoargenteus*) were the major wildlife vector until the mid-1960's when they were displaced by skunks. At present, fox rabies in Arkansas is negligible, accounting for less than 1% of the total reported cases.

SKUNK

There are six species of skunks (eastern spotted, *Spilogale putorius;* western spotted, *S. gracilis;* striped, *Mephitis mephitis;* hooded, *M. macroura;* hog-nose, *Conepatus mesoleucus;* and eastern hog-nose, *C. leuconotus*) in the United States, all of which have been involved in

reported cases of rabies (Verts, 1967; Parker, 1975). In the mid-1960's skunks replaced foxes as the major wildlife vector, and in recent years have accounted for 35-50% of the total reported rabies nationally (Winkler, 1986; Gremillion-Smith and Woolf, 1988). The vast majority of skunk rabies is reported from a skunk rabies belt extending from southern Texas and Louisiana north into Canada (Parker, 1975). Monoclonal antibody studies demonstrate that the skunk endemic area of North America originated in two separate regions (Smith *et al.*, 1986). One strain has been identified in the northern and eastern states, California, and Canada and the second with Kansas and Texas. Both viral strains are found in Missouri and Arkansas where the two epizootics are believed to have joined in the late 1960's (CDC, 1985). The presence of the two strains in Arkansas may compound the understanding of overall skunk rabies patterns in the state.

Arkansas is in the geographic range of the eastern spotted and striped skunk. While both species have been found positive for rabies, they are not distinguished by the Arkansas Department of Health. Lower densities and more secretive habits of the spotted skunk, however, have made the striped skunk the principle vector. Skunk rabies in Arkansas became prevalent in 1963-64, and since that time the skunk has become the major vector in the state. In the past nine years, skunks have accounted for 82.7% (71.8-90.2%) of the total reported rabies (Table 1, Fig. 2).

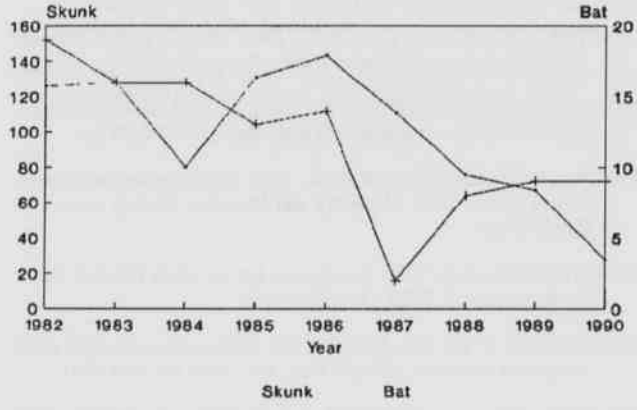

Figure 2. Reported skunk and bat rabies in Arkansas: 1982-1990.

Skunk rabies reached epizootic conditions in 1979 when a total of 301 cases were reported. During the past nine years, there has been a decline, a mild increase, and then a steady decline which reached a 20 year low of 28 reported cases in 1990 (Table 1, Fig. 2). During the epizootic years of 1977-79, Ferguson and Heidt (1980) and Heidt *et al.* (1982) conducted detailed studies into the characteristics and epidemiology of reported skunk rabies and human contact with rabid skunks. They found that March, April, and May had the highest reported incidences and that skunk rabies seemed confined to the highland areas of the state. In 1981, skunk rabies was reported in the coastal plain from Lonoke, Prairie, and Arkansas counties. Since that year, skunk rabies has been reported from most of the coastal plain counties; however, it is still most prevalent in the highland regions, averaging 69% of reported skunk rabies and ranging from 54.5% in 1986 to 78.9% in 1983.

Sixty-eight of the 75 Arkansas counties have reported skunk rabies at some point in time. The overall distribution of skunk rabies, based on data from the past nine years, indicates that 10 counties may be classified as enzootic (Table 2, Fig. 3). These ten counties have contributed 38.8% of the total skunk rabies during the past nine years. An additional 9.4% can be attributed to a one or two year outbreak in Greene, Craighead, Jackson, Stone, and Hempstead counties.

Table 2. Reported skunk rabies from ten enzootic counties in Arkansas.

County	1982	1983	1984	1985	1986	1987	1988	1989	1990	Total
Independence	10	9	3	21	14	3	1	2	1	64
White	2	12	6	9	2	7	5	4	0	47
Johnson	9	0	3	12	7	2	0	2	2	37
Pope	9	1	0	0	4	8	1	1	9	33
Faulkner	2	2	4	14	2	2	2	2	1	31
Boone	4	11	3	4	3	1	2	0	1	29
Baxter	7	4	0	3	0	0	5	9	0	28
Columbia	2	2	6	2	1	1	2	10	2	28
Washington	2	6	5	0	3	4	6	1	1	28
Howard	4	2	4	4	4	0	0	1	1	20

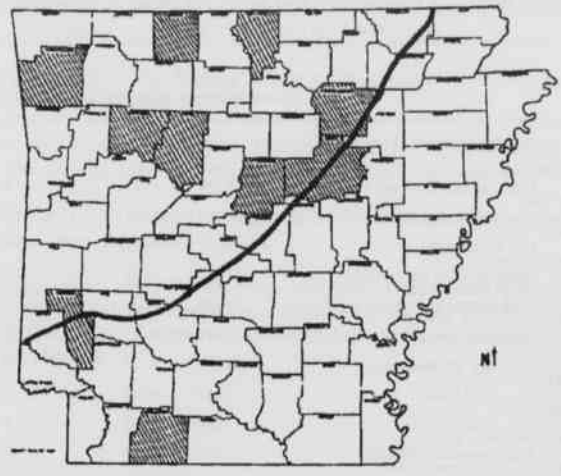

Figure 3. Ten potential enzootic skunk rabies counties in Arkansas.

The primary focus appears to be located in the Independence/White counties area. An analysis of distributional patterns for 1986-87 seems to demonstrate the importance of this focus. During 1986, Greene County reported an outbreak of 28 cases, at the same time Lawrence County reported six and Jackson County 14 cases. These contiguous counties are directly linked to Independence which had reported higher than normal cases in 1985-86. During the same time period, Stone County reported 19 cases, while the next nearest enzootic area (Baxter County) was reporting few cases. Again, the most logical source for these cases was the Independence County area. It will be interesting to follow these counties over the next several years to see if they are, in fact, the enzootic areas of the state. With the development of rabies vaccines for wildlife, the identification of enzootic foci become important adjuncts for future rabies control (Rupprecht *et al.*, 1990; Gremillion-Smith and Woolf, 1988; Bachmann *et al.*, 1990).

BAT

Bat rabies was not reported nationally until 1953 (Baer, 1975), and 1961 in Arkansas. Bats have become recognized as one of the major wildlife vectors and among the most widespread geographically in the United States (CDC, 1989). In addition, 30 of the 39 species of bats found in the continental United States have tested positive (Constantine, 1979).

In his 31 year summary of rabies in Arkansas, Heidt (1982) pointed out that reported bat rabies averaged a little over nine cases per year and accounted for 6.7% of the total reported cases in Arkansas. He also pointed out that epidemiology of bat rabies was hampered in that all 16 species of bats in Arkansas were grouped together and no identification of individual species was conducted, a situation which was corrected in 1982.

Heidt *et al.* (1987) reported that 11 species of bats had been tested between 1982-1986 and individuals from six species had tested positive. Of those, red bats *(Lasiurus borealis)* comprised 40% of the total bats submitted and 72% of the bats which tested positive.

Examination of Table 3 shows that red bats continue to comprise 40% of the individuals tested and continue to exhibit about the same percentage in terms of the total number of positive bats (68.5%). Red bats are distantly followed by big brown bats *(Eptesicus fuscus)* and hoary bats *(L. cinereus)*, with 9.0% and 7.9% respectively. In addition, hoary bats exhibited the highest percent positive with respect to submissions. The individuals in Table 3 represent 84% of the bats submitted and also testing positive for rabies.

Table 3. Summary of identified bats tested for rabies in Arkansas: 1982-90.

Species	Number Submitted/Positive (%)	Percent Total Bat Rabies
Family Vespertilionidae		
Big brown bat (Eptesicus fuscus)	193/8 (4.1)	9.0
Red bat (Lasiurus borealis)	350/61 (17.4)	68.5
Hoary bat (L. cinereus)	25/7 (28.0)	7.9
Evening bat (Nycticeius humeralis)	113/3 (2.7)	3.4
Eastern pipistrelle (Pipistrellus subflavus)	35/5 (14.3)	5.6
Silver-haired bat (Lasionycteris noctivagans)	10/0 (0.0)	0.0
Gray bat (Myotis grisescens)	12/1 (8.3)	1.1
Little brown bat (M. lucifugus)	12/0 (0.0)	0.0
Keen's bat (M. keenii)	2/0 (0.0)	0.0
Southeastern bat (M. austroriparius)	1/0 (0.0)	0.0
Eastern big-eared bat (Plecotus rafinesquii)	4/0 (0.0)	0.0
Family Molossidae		
Free-tailed bat (Tadarida brasiliensis)	111/4 (3.6)	4.5
Total	868/89	100.0

Since 1986, one additional species has been tested (southeastern bat, *Myotis austroriparius*) bringing the total species tested to 12. In addition, one gray bat *(Myotis grisescens)* has tested positive, bringing the total species which have tested positive to seven. It should be noted that the gray bat is on the Federal Endangered Species List. It must be cautioned, however, that those species which have not tested positive are not necessarily rabies-free.

Over the period of this study, bats averaged 9.8% of the total reported rabies in Arkansas (ranging from 1.6% in 1987 to 23.1% in 1990). Yearly cases ranged from two in 1987 to 19 in 1982, and averaged 11.8 cases per year. No distinct pattern could be discerned, however, trends set between 1975-1981 were continued (Table 1, Fig. 2). Furthermore, most bats submitted are from urban areas and may skew the data toward species which are highly urbanized. This trend has also been observed elsewhere (Steece *et al.*, 1982) and the implications with respect to bat rabies epidemiology are unclear.

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ORGANOCHLORINE PESTICIDE CONCENTRATIONS IN VARIOUS SPECIES OF MIGRATORY PASSERINES IN LOUISIANA

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ABSTRACT

Twenty-four specimens of southbound migratory passerines comprising 13 species were collected in northeastern Louisiana during 1986, and were subjected to gas-chromatography analyses for organochlorine pesticide compounds. Eleven of the specimens analyzed (46%) were positive for pesticides. The compounds detected were in trace amounts ranging from 1.37 to 200.14 ppb. The data indicated a further decline in pesticide burdens in birds since the ban on DDT. It also supported the hypothesis that a post-mortem breakdown of DDT to DDE may occur in avian tissues. It is hypothesized that northbound migrants may have higher pesticide burdens than fall migrants considering the continued usage of pesticides in their wintering grounds south of the United States border.

INTRODUCTION

Monitoring of pesticide levels in wildlife has intensified since the 1950's when man started the indiscriminate use of chlorinated hydrocarbons to curb populations of insect pests. Most of the investigations were carried out on raptorial species or waterfowl (Blur, 1984; Cade *et al.*, 1968; Cain, 1981). Little research has been conducted on the possible contamination of the myriads of small insectivorous, granivorous or frugivorous bird species. A single major study was conducted between 1964 and 1973 on wild North American passerine birds to study environmental organochlorine pesticide pollutants (Johnston, 1975).

The present study had two objectives: 1. To increase the knowledge of the pesticide exposure problem faced by migratory passerines along their international routes, and 2. To check the current status of avian organochlorine pesticide residues following more than a decade after the ban was imposed on their use in the United States.

MATERIALS AND METHODS

The tissues of 13 species of passerine birds, the White-eyed Vireo *(Vireo girseus)*, Red-eyed Vireo *(Vireo olivaceus)*, Yellow-throated Vireo *(Vireo flavifrons)*, Philadelphia Vireo *(Vireo philadelphicus)*, Warbling Vireo *(Vireo gilvus)*, Prothonotary Warbler *(Protonotaria citrea)*, Common Yellow-throat *(Geothlypis trichas)*, Black and White Warbler *(Mniotilta varia)*, Nashville Warbler *(Vermivora ruficapilla)*, Magnolia Warbler *(Dendroica magnolia)*, Tennessee Warbler *(Vermivora peregrina)*, Worm-eating Warbler *(Helmitheros vermivorus)*, and Indigo Bunting *(Passerina cyanea)* were analyzed in the study. The specimens were collected in Ouachita Parish, Louisiana. All of the specimens analyzed were obtained during fall of 1986 when the birds were on their southbound autumn passage. The birds were accidental tower kills by collision against television towers during migratory flight. The specimens were stored in a freezer where they remained for at least 15 months prior to the analyses.

The extraction and analyses of pesticide residues were done following the methods adopted by White (1976). The instrument used for analyses was a Hewlett Packard Model 5880A gas-chromatograph equipped with a Hewlett Packard Model 7672A automatic sampler and a Nickel 63 electron capture detector. Operating parameters followed were those of White (1976). One microliter of the sample was used in each injection. The samples were identified and quantified using a non-polar 3% SE-30 column. Identifications were verified using a polar 3% OV-17 column. The columns were 6 feet long and 2 mm in diameter.

Organochlorine compounds were identified by comparing the retention times obtained with the sample extract with those obtained with standard pesticide standard solutions. Pesticide standards were obtained from the Pesticide Monitoring Laboratory, Bay Saint Louis, Mississippi. Standard "A" contained the following pesticides: heptachlor, heptachlor epoxide, chlordane, dieldrin, endrin, o, p'-DDT, and p,p'-DDT in known concentrations. Standard "B" contained: aldrin, o,p'-DDE, p,p'-DDE, and p,p'-TDE in known concentrations.

RESULTS AND DISCUSSION

Eleven of the 24 bird samples analysed (46%) were found to contain pesticide residues (Table 1). Nine of the 13 species collected were positive for pesticides. Four compounds were detected viz. p,p'-DDE, o,p'-DDE, dieldrin and heptachlor epoxide. p,p'-DDE was the most predominant residue showing up in 38% of the samples. Dieldrin followed next in the order of predominance (16%) followed by o,p'-DDE (8%) and heptachlor epoxide (4%). White (1976) had also detected a predominance of DDE in his analyses of duck liver tissues. Heath (1969) and Dindal and Peterle (1968) reported DDE was the major residue in their analyses of bird tissues. Studies of migratory song birds by Johnston (1975) also revealed more DDE residues than any other compound. DDT, the metabolic predecessor of DDE, was not detected during the present study. A possible explanation for the absence of DDT and predominance of DDE in the samples could be that most of the bird specimens were collected and stored in a freezer for at least 15 months before the analyses

Table 1. Organochlorine pesticide concentrations detected in eleven passerine birds collected in northeastern Louisiana during fall 1986.

Bird Species	Pesticide (ppb)			
	o,p'-DDE	p,p'-DDE	Dieldrin	Heptachlor epoxide
White-eyed Vireo	nd	1.37	nd	nd
Prothonotary Warbler	nd	77.62	nd	nd
Yellow-throated Vireo	nd	nd	12.48	nd
Yellow-throated Vireo	nd	77.48	37.91	nd
Yellow-throated Vireo	nd	200.14	nd	nd
Common Yellow-throat	nd	55.40	nd	nd
Black & White Warbler	nd	72.51	69.39	nd
Nashville Warbler	nd	108.34	nd	nd
Warbling Vireo	26.21	29.91	16.58	13.79
Worm eating Warbler	nd	45.86	nd	nd
Indigo Bunting	5.25	nd	nd	nd

were done. French and Jeffries (1969) found that in the anaerobic conditions existing after death, p,p'-DDT was broken down to p,p'-DDE in avian tissues. Later, White (1976) supported these findings in his studies on pesticide levels of duck livers, when he noted that most of the livers analyzed after 60 days in storage contained no DDT residues. The present study thus increases the evidence of the post-mortem breakdown of DDT to DDE.

All the bird samples analyzed were tower kills collected during fall migration, when the birds were on the southbound post-breeding movement. Two previous studies indicate that autumnal samples of migratory birds killed at television towers and ceilometers nearly always contained a high proportion of immature or birds-of-the-year individuals (Stoddard, 1962; Stoddard and Norris, 1967). In light of these findings, it seems more reasonable to assume that the birds in the present study had been contaminated in their summer range in North America.

Organochlorine pesticide residues were detected in trace amounts ranging from 1.37 to 200.14 ppb (Table 1). The highest concentration was found in a Yellow-throated Vireo. All four compounds were detected in a Warbling Vireo, which had a combined pesticide burden of 86.51 ppb. The mean DDE level detected was 60.34 ppb, well below the acceptable level of 4,000 ppb. The low concentrations are attributable to the decline in the usage of organochlorine pesticides in the U.S. over the past two decades. Johnson (1975) reported a progressive decline in DDT residues in migratory song birds between 1964 and 1973 and correlated it with the decreased use of DDT in the U.S. during the same period. In his studies, the mean annual concentration decreased from 17.80 ppm in 1964 to 2.06 ppm (2,060 ppb) in 1973. The data collected in the present study clearly indicated that a further decline in residue levels has occurred since 1973.

Even though the residue levels are negligible, the fact that they are present indicates that there are still areas across North America which have remnants of the pesticides used years ago. The levels in these areas could be very low and declining in the passage of time, but the risks of biological magnification along food chains cannot be ruled out. Migratory song birds form part of a subterminal trophic level wherein pesticide residues could play important roles in population dynamics. The organisms of trophic levels immediately above are prone to the effects of biological magnification. Similar concern had been expressed earlier by Cade *et al.* (1968) and Johnston (1975).

In the 1960's and 1970's Johnston (1975), in his studies on migratory song birds, found more pesticide residues in southbound autumn migrants than in northbound spring migrants. This was expected because at that time spraying was heavy in the U.S. In recent years, however, the use of these pesticides has ceased in the U.S. The more agriculture dependent, developing nations of Central and South America, the wintering range of many of our song birds, persist in the application of organochlorine pesticides. Some studies have suggested that birds wintering south of the U.S. border are exposed to higher levels of organochlorine pesticides than nonmigrant forms (Fleming *et al.*, 1983). Based on these facts, it is hypothesized that the trend could be reversed in recent years: northbound migrants carrying heavier burdens in their tissues than southbound ones.

A similar case was reported in the Old World by Persson (1972) who detected a much higher DDT content in spring than in autumn for Whitethroats *(Sylvia communi)* migrating northward across North Africa and Europe to their late summer range in Sweden where DDThas been banned since 1970. The inability to obtain spring specimens for the present study has made it impossible to verify this possibility, but leaves this interesting aspect open for future study.

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LANDOWNER REPORTS OF DEER HUNTER DAMAGE IN ARKANSAS

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ABSTRACT

Damage to property from deer hunters, though usually not discovered immediately, is a problem for many Arkansans. A questionnaire survey was mailed to 3,773 rural landowners in Arkansas to determine the type and cost of damage suffered from hunters. Thirty-five percent reported minor problems, and 15% reported severe damage from hunters. The most common problems caused by hunters were fence cutting (33%), severe littering (16%), road damage (13%), crop damage (10%), cattle shot (8%), gates left open (6%), and trespassing (6%). Eighty-three (5%) of the landowners reported damage costs of $500 or more; one sustained a $15,000 loss. Total state-wide losses are estimated at almost $15 million per year. Solutions lie in cultivating a stewardship position among landowners and a stronger ethic of respect among hunters. Mandatory hunter education programs can help instill hunter ethics, while posting laws can provide the administrative mechanism to control access and exposure.

INTRODUCTION

White-tailed deer *(Odocoileus virgianianus)* are an important natural resource in Arkansas and a source of enjoyment for many residents. During the 1985-86 hunting season, the Arkansas Game and Fish Commission sold an estimated 217,600 resident hunting licenses. During the same year, Arkansans legally harvested about 60,100 deer (Pollock and Cornelius, 1986). The estimated number of deer in Arkansas has increased steadily since restocking efforts of the 1940s, from 500 in 1930 to 500,000 in 1986 (Low, 1986). While the total legal kill (checked kill) and herd size estimation is subject to error, the number of deer and the number of deer killed have increased over time. This is despite a steady decline in the number of licensed deer hunters in the state since 1981 (Kluender *et al.*, 1988).

Associated with the hunt, access to hunting areas and concurrent damage to landowners' property is a perennial question and source of problems. Beginning in the mid-1980s, forest industry landowners in southern Arkansas began leasing hunting rights to clubs. While leasing was initiated to improve access control and to generate additional revenue for the companies, it changed hunting patterns in the area. Leased areas are no longer on a first come basis, a policy that often lead to confrontations among groups of hunters and between hunters and landowners. Some companies have promoted surrogate ownership by lessees with corresponding good results. Many hunt clubs patrol leases and watch for vandalism or other problems. However, for many hunters without access to industry or public lands, finding a place to hunt is more involved and is dependent on the availability of nonindustrial lands.

A landowner's property is susceptible to both intentional and unwitting damage by the public. In a 1978 forest industry survey in the southeastern United States, Kluender (1978) found that hunting and off-road vehicle riding were the primary uses of industrial lands by sportsmen. Associated with these pursuits were various types of property abuse and damage ranging from fires that got out of control, trash dumping and, road damage during bad weather. While lessors can act against lease holders through contract provisions, landowners who do not lease have little or no protection from damage by known or unknown hunters. Often, damage is discovered long after it is committed, leaving the landowner with the costly problem of repair or replacement of fences, roads, and equipment.

Owens *et al.* (1985) found similar patterns in Arkansas for industrial and large, private ownerships (>405 ha) to those found by Kluender (1978). In their study they found that although public uses included, in decreasing frequency, hunting, trash dumping, firewood gathering, fishing, and ATVriding. The most important problems for landowners were litter, illegal firewood cutting, road damage, arson, and timber damage.

To date no one has measured the losses due to deer hunters in Arkansas on farms and small ownerships. There is adequate reason to believe that the public may hold different attitudes toward industrial and large nonindustrial landowners (>405 ha) than toward small landowners. Kluender (1978) found that industrial ownerships are often viewed as quasi-public lands. Accordingly, one might expect to find a different type damage and severity of damage on nonindustrial private than forest industry lands. The objectives of this study were to determine the level of damage to nonindustrial lands and property sustained by landowners from hunters and to determine landowner attitudes toward hunting and hunters.

METHODS

A questionnaire survey was mailed to 3,773 rural landowners in Arkansas during January 1987. The questionnaire gathered basic information about the landowner, property use, attitudes toward deer, damage caused by hunters, and policies used to deal with hunters. Landowner variables included age, sex, household income, residence on property and principal land use. Questions about attitudes and perceptions relating to deer asked about the landowner's wishes for deer herd size and perception of the size and change in deer herd. Questions about hunters and policies questioned type and severity of damage by hunters and landowner attitudes toward leasing and access control.

Personnel from the Arkansas Cooperative Extension Service randomly selected names from lists of rural landowners maintained at each county Cooperative Extension Service office. The number of landowners selected from each county was proportional to the number of farm operators it contained, (U.S. Dept. Commerce, 1984) and ranged from 11 to 208. The sample size was selected to provide bounds on error of estimates for proportions (Mendenhall *et al.*, 1971) of 2% if all surveys were returned.

Data were summarized and analyzed using the statistical software SPSS/PC+ (Norusis, 1988). Contingency table analysis was used to evaluate associations between attitudes and perceptions of damage and landowner characteristics. Analysis of variance was used to test for differences in mean damage in dollars by region. Statistical significance was accepted at the 0.05 probability level.

RESULTS

DESCRIPTION OF RESPONDENTS AND FARMS

We received 1,695 (45%) responses to our survey, which provided 2.4% bounds on error of estimates for proportions. Normal response rates for mail surveys average around 10% (Alrek and Settle, 1985). Response rates did not differ by region of the state (Figure 1). We did not survey nonrespondents; however, the landowner described in this study was similar to that found by Greene and Blatner (1986) for Arkansas. Therefore, we conclude that the sample is sound, and statistical inference (Cochran, 1977) is acceptable within the prescribed bounds of error and, further, is adequate for comparison across regions.

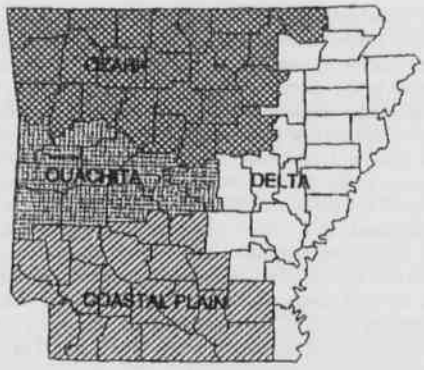

Figure1.
Regions of Arkansas used in the deer hunter damage survey.

Because of the small tracts of land and fragmented landownership patterns in the Ozark Mountains the greatest proportion (51%) of the total responding landowners was from this region. The Coastal Plain had 14% of the respondents with the Ouachita Mountains and the Delta consisting of 14% and 21%, respectively. Across regions, landowner descriptive statistics did not vary; most respondents were white (99%) (X^2=12.19, p=.080) and male (95%) (X^2=6.02, p=.420) with more than 12 years of education (46%) (x=13 yrs, sd=3.13) (X^2=82.59, p=.256). Statewide, most (87%) lived on their land. A small proportion (12%) had household incomes of less than $10,000, 25% had incomes of $10,001-$20,000, 25% had incomes of $20,001-$30,000, and 37% had incomes of more than $30,000. About one-third (31%) of respondents received less than 10% of their household income from their land. The second third (34%) received 10-75% of their income from their property, and the final third (35%) received more than 75% of their income from their land. Residents of the Delta were somewhat less likely than respondents from other regions to live on their land (77 vs. 89%, respectively) (F=14.00, p<.001). Delta residents also derived a higher proportion of their household income from the land itself than did residents of other regions (F=71.60, p<.001). For example, 70% of Delta respondents derived more than 75% of their income from their land, while only 26% of residents from other regions were similarly dependent on their property.

In an *ex post* test, landowners were divided into four groups based on whether they lived on their land and whether they were dependent (>50% of household income) on the land for their living. In the Ouachita and Ozark mountains, landowners were much less likely to be dependent on the land for their living (X^2=250.56, p<.001). Respondents not dependent on their land accounted for 66% in the Ouachita and Ozark mountains versus 56% in the Coastal Plain and 22% in the Delta. Most of these were either small farmers who supplemented other income with farm proceeds or they were retired or otherwise independent individuals who owned the land for personal reasons.

DEER SIGHTINGS AND VALUE

Most respondents (77%) had seen deer on their property during the preceding year. The average respondent estimated seeing as many as 6 deer at one time on his or her land. The average Coastal Plain respondent saw over twice as many deer as residents of other regions (11 vs. 5 deer, respectively) (F=33.760, p<.001). The maximum number of deer sighted at one time did not differ among the Delta, Ouachita and Ozark mountains regions. Opinion was divided about changes in deer numbers during the previous five years, with 21% of the respondents estimating that deer numbers had decreased, 31% stated that the number had stayed the same and 28% stated that they had increased. Ouachita and Ozark residents most often felt that deer numbers had decreased. Residents of the Coastal Plain believed most often that deer numbers were the same as in the five previous years. Delta residents reported most often that deer numbers had increased (X^2=58.978, p<.001).

Most respondents (83%) acknowledged that deer had an aesthetic value and wanted deer on their land. Most respondents wished deer numbers in their county to increase (64%) or remain constant (30%). Only 6% of all respondents wanted deer numbers to decrease. Most of the people who wanted deer numbers to not increase or to decline were residents of the Coastal Plain (X^2=200.189, p<.001).

DEER HUNTING AND DAMAGE BY HUNTERS

Most respondents (60%) said they hunted deer, including 16% who had not hunted during the past year. Residents of the Coastal Plain and Delta were more likely than residents of the Ouachita and Ozark regions to hunt deer (68% and 72% vs. 57% and 53%, respectively) (X^2=87.387, p<.001).

Fifty percent of the landowners surveyed reported problems with deer hunters using their lands; 35% reported only minor problems, but 15% reported property damage from hunters. Landowners in the Coastal Plain were more likely to have had damage from hunters; respondents from the Ouachita and Ozark mountains were least likely to have had damage from hunters (X^2=20.342, p=.016).

Among the respondents with damage, the most common types were fence cutting (33%), severe littering (16%), road damage (13%), cattle shot (8%), crop damage (10%), gates left open (6%), and trespassing (6%). Other problems included careless shooting (3%), spotlighting deer (2%), stolen property (1%), locks cut (1%), and miscellaneous vandalism (1%) (Table 1). Landowners with damage related to deer hunting had an

Table 1. Distribution of damage cases and financial losses reported by Arkansas landowners who had damage caused by hunters.

	State	Coastal Plain	Ouachita	Ozark	Delta	Average Occurrence	Maximum Loss	Total Loss State Wide[1]
Number of responses	784	129	103	382	169	623	13,000	14,937,667
	Proportion of Responses (%)					Damage ($)		
Problem								
Fences	33	39	36	34	17	358	4,000	2,834,689
Littering	16	8	10	20	18	90	200	345,518
Road Damage	13	15	7	6	30	1,622	15,000	5,059,443
Damage to Crop	10	11	9	9	14	1,006	6,000	2,413,829
Cattle Shot	8	11	9	8	4	851	5,000	1,635,533
Gates	6	6	9	7	1	157	350	226,027
Trespassing	6	2	4	6	8	550	1,000	791,813
Careless Shooters	3	5	4	3	2			
Spot Light Deer	2	0	1	2	5	166	320	79,661
Dogs Ran Deer	2	0	4	2	1	38	50	18,236
Property Stolen	1	1	1	2	0	195	300	46,789
Locks Cut	1	1	0	1	1	202	400	48,469
Vandalize Property	1	0	3	0	0	6,000	7,000	1,439,660

[1]Estimated total loss by category based on number of farm owners in the state and average cost of damage in a given category weighed by the likelihood of occurrence.

average loss of $623. Average loss did not differ by region (F=.828, p=.480). The most expensive damages were vandalism, road damage, and crop damage (Table 1). Eighty-three landowners (5% of the total sample) reported damages of $500 or more; four reported damages of $5,000 or more, and one sustained a $15,000 loss. Although there was not a significant difference in average losses by region for those with damages, totals were $32,903 in the Coastal Plain, $28,535 in the Ouachita Mountains, $49,280 in the Ozark Mountains and $30,948 in the Delta, for a state total of $141,666 for the 216 respondents who reported monetary damage. Expanding these results to the 50,525 rural land owners in the state (U.S. Dept. Commerce, 1984) gives an estimated 23,994 owners with damage statewide and a total damage estimate of $14,937,667 per year.

Despite problems with hunters, many landowners (43%) permitted public hunting at no charge. The percentage of landowners permitting free public access did not differ by region (X^2=4.013, p=.675). Those with hunter damage were less likely than those without to permit free public access for deer hunting (37% versus 45%).

Other respondents posted their land with "no hunting" (33%) or "hunting by permission only" signs (20%). Few landowners (14%) posted as specified in Arkansas Act 1090 of 1985, which requires boundaries to be marked with purple paint or with signs. Landowners with hunter damage were much more likely than those without damage to post their land (X^2=205.24, p<.001). Landowners most often posted their land because they wanted to know who was on the property (72%). Most (60%) said they posted because of problems with hunters; 12% posted because their land had been damaged by off-road vehicles. Other common reasons for posting were to reserve the land for family use (45%) and fear of liability (36%). Most respondents permitted friends (72%), family members (55%), and strangers who asked permission (27%) to hunt on their property.

Only 4% of the responding landowners leased their lands for deer hunting. Coastal Plain and Ouachita residents charged average fees of $2.14 and $2.33 per ac, respectively ($5.29 and $5.76 per ha, respectively). Ozark Mountain and Delta residents charged an average of $9.38 and $18.44 per ac, respectively ($23.17 and $45.54 per ha.).

DISCUSSION

The results of this study found types of property damage similar to previous studies of Kluender (1978) and Owen *et al.*, (1985), suggesting that damage associated with public use may not vary with the size of the holding or ownership class. Public agency efforts to control damage by hunters focus on improving relationships between hunters and landowners. Principal efforts are aimed at hunter education. The Arkansas Game and Fish Commission requires individuals born after December 31,1968, to attend a 10-hour hunter education course to obtain a hunting license (AG&FC, 1986). The course covers game laws and regulations, but also teaches basic hunter skills and ethical responsibility for personal actions. The text for this course is provided by the National Rifle Association (NRA, 1982). Students spend 1 1/2 of the 10 hours on ethical responsibilities of hunting, including hunter-landowner relations. All the major types of hunter-caused damage listed by respondents are specifically covered in the student text. To date, however, there has been no broad-scale assessment of the success of this course.

Until the 1985 posting and trespass law (Act 1090, "The Purple Paint Law"), landowners who held timbered lands had no legal recourse for keeping individuals off their property; nonetheless, Act 1090 only applied to enclosed forest land. Act 35 of 1989 significantly tightened the terms of trespass by allowing all real property, including unenclosed forest land, to be posted. It is now a Class 'B' misdemeanor to enter onto land that is marked according to Act 35 without written permission of the owner. The two trespass laws were considered critical steps in the protection of landowners. Wider publicity of these laws and the fact that all property can now be legally posted should be expected to result in less damage, because hunters who obtain the required oral or written permission to hunt on posted land will be directly accountable to the landowner.

Kluender (1978) summarized, in three categories, industry attempts to cope with losses attributable to sportsmen: 1) limiting access by closing some areas; 2) promoting surrogate ownership attitudes through leasing hunting rights and cooperation with other landowners, and 3) permit systems to regulate access by individuals. Owen *et al.* (1985) prescribed a two-fold approach to the sportsman-landowner problem. First, the development of positive non-abusive habits on the part of users, and second, public recognition that private landowners are "custodians of wildlife and stewards of the land" and, thus, need to be compensated and protected.

The similarities in the recommendations of these two studies suggest the dual nature of the problem and a workable solution. A stronger, widespread understanding of hunter responsibilities can be brought about by additional education programs and a more formalized contract between hunters and landowners. Leasing or daily permit systems may be advantageous. Several states now have such programs. For example, Virginia's Operation RESPECT (a hunter-landowner daily fee system) and Missouri's SPORT, (Sportsmen Policing Our Ranks Together) have helped reduce hunter-landowner problems.

Leopold (1933) viewed landowners as being responsible stewards of wildlife and the land. In this context the landowner becomes a protector of the land and wildlife resources, providing controlled access to those who will respect and not abuse the resources open to them. Without this attitude, it is apparent that conflicts between users and landowners will continue and may escalate. An additional factor is important. Consider the reduction in lands open to hunters. Access to forest industry lands has been severely restricted during the last five years through leasing arrangements. Some public lands have been set aside for uses incompatible with hunting (Kluender and Greene, 1990). And the nonindustrial forest land base has been declining since 1962 (Kluender and Willett, 1989). Pressure on nonindustrial lands will continue to increase. Owner-hunter relations must change to accommodate this pressure.

Targeted education programs can serve both hunters and landowners. Inculcation of ethical principles remains the purview of the individual. While social pressure can mitigate and even mandate behavior of both hunters and landowners, the roots of consistent ethical conduct reside in individual personal decisions reinforced by consistent practice. Controlled access can help provide the administrative mechanism within which both hunters and landowners can play out their roles. Benefits of control access include a reduction in landowner exposure to damage while permitting hunters to enjoy their sport.

A final, although least desirable, method of reducing damage to landowner property is stricter enforcement of trespass laws. In most situations, a verbal confrontation between a landowner and a trespasser is enough to cause an offender to leave peacefully. While landowners have always had the option of resorting to civil action for damages by hunters, this course has been used only occasionally because of legal problems and fear of retribution from hunters. Landowners are now in a stronger legal position regarding trespass; civil action for damages should decrease.

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PHOTOREACTIVATION OF UV-INDUCED DAMAGE IN G1 PHASE XENOPUS CELLS THAT LEADS TO SISTER CHROMATID EXCHANGED AND CELL DEATH

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ABSTRACT

Experiments were conducted with the A87 *Xenopus* tissue culture cell line which centered on use of the line's efficient photoreactivation (PR) mechanism to: (1) determine the extent to which sister chromatid exchanges (SCEs), induced by exposing early G1 phase cells to low UV fluenced, are photoreactivable, and (2) determine the extent to which the photoreactivable SCEs resulting from these low UV fluences constitute lethal lesions. For the first determination, UV fluences – SCE frequency relations and UV fluence + PR fluence – SCE frequency relations were established for UV fluences in the range 0 - 12 J/m^2 and a single PR fluence of 22,000 J/m^2. Comparison of these relations indicated that the cells photoreactivated a predominant fraction (near .70) of the induced SCEs. For the second determination, a detailed time course of PR of induced SCEs relation and a time course of PR of induced lethality relation were established for the cells, using a single UV fluence of 5.0 J/m^2 and a single PR fluence of 22,000 J/M^2. Comparison of these relations indicated that few, if any, photoreactivable SCEs constituted photoreactivable lethal lesions. This comparison also suggested that further high resolution cytological studies of time course of PR of UV-induced SCEs may reveal additional relations between repair of SCEs and changes in vertebrate chromosome structure as cells progress through interphase.

INTRODUCTION

Sister chromatid exchanges (SCEs) result from interchanges between DNA molecules at homologous loci within replicating chromosomes. The biological significance of SCE production is not known. Knowledge of the mechanisms of SCE production are incomplete and present interest in their exploration derives, in part, from the notion that understanding of these mechanisms will assist in identifying the biological significance of SCEs. Interest in the exploration of these mechanisms also stems from results of previous studies (Latt, 1981) indicating numerous parallels between SCE induction and mutagenesis, including the fact that many agents that are efficient at producing SCEs are also highly mutagenic. These parallels strongly suggest that studies of SCEinduction might yield useful results that could be extrapolated to mutagenesis and vice versa. Since a bromodeoxyuridine (BrdU0-Giemsa dye differential staining technique is now available for assaying SCEs, that is much more efficient and easily applied than available techniques for assaying mutations (Perry and Wolff, 1974), studies of the mechanisms of SCE induction are receiving increasing emphasis. There studies are designed primarily to describe the lesions induced in DNA that lead to SCEs and intracellular processes which express them.

Since shortwave UV is exceptionally effective at producing both SCEs and mutations, considerable attention has been focused on attempts to describe the primary DNA lesions induced by this agent that lead to SCEs and related expression mechanisms. The observation that the major primary lesions induced in DNA by UV are pyrimidine dimers (Sutherland, 1981) led a number of investigators to perform experiments designed specifically to relate pyrimidine dimer induction to SCE induction. The general approach used in these experiments was to determine the extent of photoreactivation (PR) of UV-induced SCEs in PR competent cells. This approach was based on the previous observation (Sutherland, 1981) that, apparently, pyrimidine dimers are the only photoreactivable DNA lesions, implying that SCEs could be photoreactivated in PR competent cells "only" if pyrimidine dimers are lesions that lead to SCEs. Kato (1974) reported successful attempts to photoreactivate UV-induced SCE production in rat kangaroo *(Potorous)* cells. However, Wolff (1978) was unable to repeat Kato's (1974) experiments. More recently, Ishizaki *et al.* (1980) made another attempt to photoreactivate UV-induced SCEs in *Photorous* cells and obtained results which were more consistent with Kato's observations. Wolff (1978) also failed to observe PR of SCEs induced by UV in chick embryonic cells, although he did detect chemical evidence of a significant level of PR of the induced pyrimidine dimers in these cells. In contrast, Natarajan *et al.* (1980) reported a successful attempt to photoreactivate significant levels of both pyrimidine dimers and SCEs, induced by UV in chick embryonic cells. Both *Potorous* cells and chick embryonic cells possess negative properties that detract from their suitability as good materials for studies of PR of SCE formation; the chick cells have a very difficult karyotype for SCE and other chromosome analysis (Natarajan *et. al.* 1980), while *Potorous* cells possess a relatively inefficient PR mechanism (Wolff, 1978). These facts coupled with observations by Little (1978), that SCE induction by some agents is very sensitive to experimental protocol, suggest that differences (which might normally appear minor) in experimental protocols and accompanying data analysis used by Wolff and the other investigators might account, at least in part, for the contradictory observations. The A8W243 *Xenopus* lines derived from the A8W243 line, do not possess the negative properties possessed by the *Potorous* and chick cells. Instead, *Xenopus* cells possess very stable karyotypes, consisting of relatively large metacentric and submetacentric chromosomes that constitute quite suitable material for SCE analysis. Furthermore, these cells possess mechanisms for PR of UV-induced lethal damage and chromosomal abberrations not surpassed (to our knowledge) by any other cell line. Therefore, it appeared to us that these cell lines would constitute quite suitable material for PR studies which might assist in resolving the apparent conflict in the data mentioned above, and, perhaps, otherwise lead to significant additions to our knowledge of SCE induction by UV and its biological significances. We describe here the detail of our first experimentation in this direction, which was primarily designed to enhance knowledge of the role of UV-induced photoreactivable pyrimidine dimers (PPds) in UV-induced SCE production and the role of UV-induced photoreactivable SCEs (PSCEs) in UV-induced cell-killing.

MATERIALS AND METHODS

All experimentation was performed with the A87 *Xenopus* cell line, which was recently cloned from the A8W243 line described by Griggs and Bender (1972). Monolayers of A87 cells were routinely maintained in the dark at 22°C in large plastic bottles (Falcon) in F10 medium (Gibco), supplemented with 10 percent foetal calf serum (Hazleton) and buffered with HEPES (Sigma).

In exponential growth at 22°C, the cells exhibited a plating efficiency near 92%, and an average cycle time of 38 hours (12 hours G1; 18 hours S; 5.5 hours G2; 2.5 hours M). The line has a relatively stable karyotype with virtually 96 percent of the cells possession 36 easily identifiable chromosomes (Figure 1a) and constitutes relatively good cytological material for various chromosomes analyses, including SCE detection.

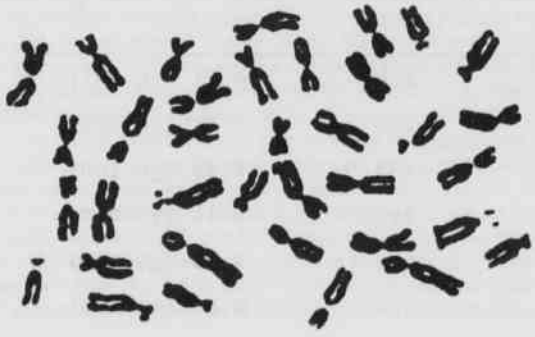

Figure 1a. Photograph of a normal set of A87 *Xenopus* chromosomes.

Techniques employed for single cell plating, colony assays, survival curve analysis, cell synchronizations, mitotic index determinations, mitotic arrest, and preparation of chromosome spreads did not differ significantly from those described in detail previously (Griggs and Bender, 1972; Griggs and Orr, 1979; Griggs and Payne, 1981; Kulp and Griggs, 1989).

All UVand PR irradiations were carried out with the same apparatus as described by Griggs and Orr (1979). UV was administered under red light at a fluence of 5 J/m²/sec at 22°C. The PR scheme used was the same as the one determined by Kulp and Griggs (1989) to be optimum for PR of UV-induced aberrations in the closely related A86 *Xenopus* line. A preliminary experiment to determine how the cells progress through G1 phase into S phase was carried out with synchronous cell cultures following 5 J/m² UV fluence, 5 J/m² UV fluence + 22,000 J/m² PR fluence, and a control with no UV fluence or PR fluence. The results are shown in Figure 2.

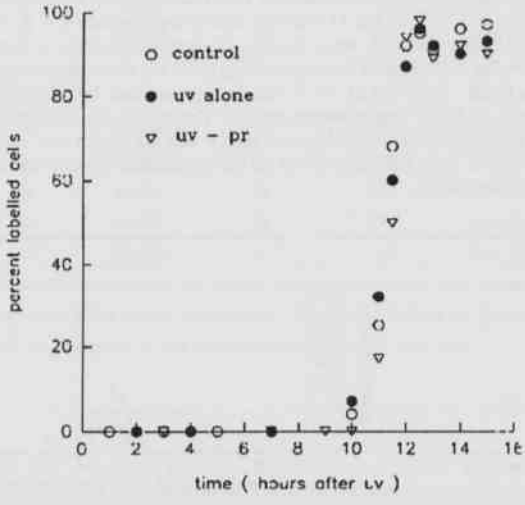

Figure 2. Time course curve to determine how the cells progress through G1 phase and into S phase following no fluences (open circles), 5 J/m² UV fluence (filled circles), and 5 J/m² UV fluence + 22,000 J/m² PR fluence (triangles).

Synchronous *Xenopus* cell culture were used in the experimentation for two reasons: (1) Analysis of effects induced by UV and related repair in non-synchronous cultures is far more complex than in synchronous cultures because cells in different phases of the cell cycle exhibit significantly different radiation sensitivities and repair potentials. (2) The SCE detection technique used essentially precluded use of non-synchronous cultures.

A 5-bromodeoxyuridine (BrdU) labelling-Giemsa differential staining method, similar to that developed by Perry and Wolff (1974), was used for detecting SCEs produced by UV and/or PR treatments of synchronous monolayers of G1 cells and their progeny. Monolayers of cells, synchronized in early G1 phase, were allowed to progress through S phase in medium containing BrdU to a final concentration of 5 x 10^{-4} molar or 0.0 molar. Shortly after the passage of the cells through S phase, the medium was removed and replaced with non-BrdU medium. Mitotic selection at this first mitosis produced cultures of unifiliarly labelled cells or non-labelled cells that were then allowed to progress through G1 and early S phase in non-BrdU medium to the second mitosis. As the cells progressed through the second G1 and early S phases, they were exposed to the desired fluences of UV and/or PR light. When the treated cells reached the second mitosis, samples of metaphase cells were collected with colcemid (Sigma). Metaphase spreads prepared from these samples on microscope slides were stained by the following procedures in the order listed: (1) The slides were completely covered with drops of Hoechst 33258 solution (.150 mg/ml) in Sorensen's buffer, let stand in the dark for 25 minutes, and then rinsed thoroughly in distilled water. (2) Slides were mounted with 2 x SSC (0.3 M NaCl, 0.03 M sodium citrate) and exposed to a bank of ultraviolet lights (Westinghouse F20) for 2 hours. (3) Coverslips were carefully removed from the slides and, after a thorough rinse in distilled water, each slide was stained for 5 minutes in freshly prepared Giemsa solution (5 percent Gurr's R66 in Sorensen's buffer, pH 7.0). This differential method produces faint staining of chromatids which contain unifiliarly BrdU-substituted DNAand bright staining of chromatids which contain no BrdU (Figure 1b).

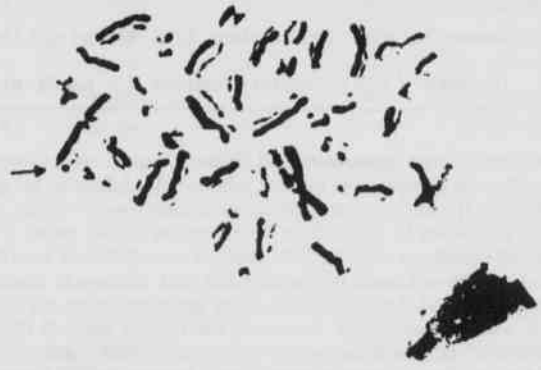

Figure 1b. Photograph of a set of A87 *Xenopus* chromosomes following the BrdU labelling-Giemsa differential staining method and showing a sister chromatid exchange (arrow).

RESULTS AND DISCUSSION

Table 1 contains data from the initial set of experiments performed. These experiments were designed to obtain an indication of the extent of PR of UV-induced SCEs in A87 cells. The starting point in each of these experiments was UV irradiation of a large set of synchronous cultures of early G1 phase cells, that were unifiliarly labelled with BrdU. Cultures of cells in early G1 phase were used because cultures obtained by mitotic selection possess their best synchrony while in early G1 phase, and the complexity of analysis of effects induced in *Xenopus* cultures by UV is significantly greater in cultures with diminished synchrony. The set of UV exposed cultures was then subdivided into four subsets (A,B,C,D).

Table 1. PR of lesions, induced in early G1 phase A87 cells by UV, that lead to SCEs.

Experiment number*	UV fluence (J/m^2)	PR fluence (J/m^2)	Time range for cell collection by colcemid (hrs after UV)	Number of cells scored	Number SCEs per cell (± standard error)
1	0	0	34 - 45	250	0.01 (±0.001)
2	0	22,000	34 - 45	250	0.07 (±0.001)
3	1	0	40 - 58	250	1.45 (±0.100)
4	1	22,000	36 - 54	250	0.32 (±0.010)
5	2	0	45 - 60	250	2.50 (±0.150)
6	2	22,000	38 - 50	250	0.80 (±0.030)
7	5	0	72 - 100	250	6.80 (±1.120)
8	5	22,000	55 - 80	250	1.40 (±0.160)
9	8	0	80 - 105	250	7.90 (±1.390)
10	8	22,000	65 - 90	250	2.00 (±0.180)
11	12	0	90 - 120	250	9.10 (±1.680)
12	12	22,000	75 - 100	250	2.80 (±0.210)

* PR was administered to synchronous cultures (unifiliarly labelled with BrdU) immediately following the termination of UV. Two samples of mitotic cells, equal in number (125), were scored in each experiment.

Subsets A and B were photoreactivated. Subsets A and C were allowed to progress through interphase to the first mitosis (M1) following the exposures. Subsets B and D were used for detailed mitotic index studies, some of which are shown in Figure 3, to determine the mitotic peaks at M1. Samples of metaphase cells for SCE analysis were collected from these mitotic peaks by colcemid treatments. The data of the odd numbered experiments reveal that SCE frequencies are significant and clearly increase with increasing UV fluence in the fluence range 0-12 J/m^2. Comparison of the data of the control experiment (1 and 2) indicates that the PR fluence alone effects a relatively small increase in SCE frequency. This increase is probably closely related to the photolysis of bromine in the BrdU labelled DNA (Hutchinson, 1973). Comparison of the data from experiments 3, 5, 7, 9, and 11 with the data of experiments 4, 6, 8, 10, and 12 reveals that the cells were capable of photoreactivating a relatively high level of UV-induced damage leading to SCEs; for example, approximately (9.10 - 2.80/ 9.10) .70 of the damage induced by 12.0 J/m^2 UV that leads to SCEs was photoreactivated. These data are consistent with those reported by Kato (1974), and imply that A87 cells can express a subset (of at least moderate size) of the pyrimidine dimers induced in their DNAas SCEs.

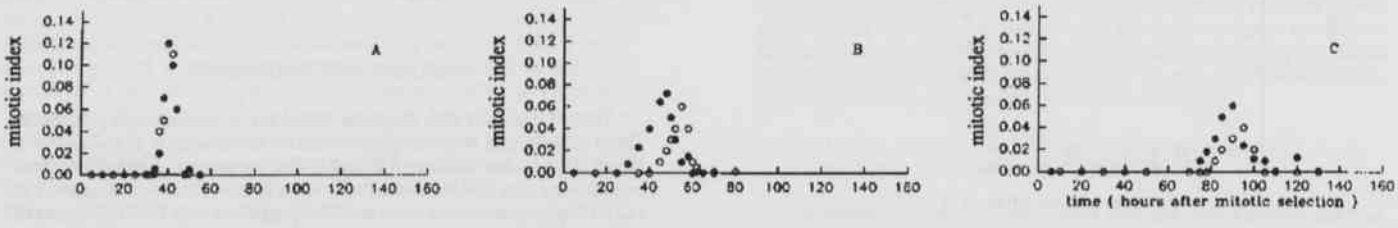

Figure 3. Mitotic index curves to determine the mitotic peaks at the first mitosis of the cells following (A) no UV fluence (filled circles) and 22,000 J/m^2 PR fluence only (open circles), (B) 1 J/m^2 UV fluence (filled circles) and 1 J/m^2 UV fluence + 22,000 J/m^2 UV fluence (open circles) and, (C) 12 J/m^2 UV fluence (filled circles) and 12 J/m^2 UV fluence + 22,000 J/m^2 PR fluence (open circles).

Previous detailed studies of the time course of PR of photoreactivable lethal lesions (PLLs) induced in early G1 phase *Xenopus* cells by UV (Griggs and Payne, 1981) indicated that these lesions could be efficiently photoreactivated shortly after the UV exposure, but as the damaged cells progressed through G1 phase they rapidly lost this ability. This observation, coupled with the data of Table 1, suggested our first attempt to enhance knowledge of the biological significance of SCEs. The attempt centered on experimentation designed to obtain an indication of the extent to which PSCEs in early G1 phase A87 cells constitute PLLs. It was reasoned that, if a substantial fraction of the PSCEs induced in early G1 phase by a given UV fluence are PLLs, then the kinetics for PR of these SCEs as a function of time following the UV exposure (i.e., time course of PR) would parallel the kinetics of the time course of PR of the PLLs induced by the PR fluences. Thus, time course of PR experiments of this nature were performed and the resulting data are displayed in Table 2 and 3. These experiments were composed of four steps: (1) sets of synchronous cultures of (BrdU labelled) G1 phase cells, one set for each experiment, were exposed to a UV fluence of 5.0 J/m^2 one hour after mitotic selection. (2) All but one (control) of these sets of UV irradiated cultures were then exposed to 22,000 J/m^2 PR light after the termination of UV at varying time intervals (a different interval for each set) following the exposure. (3) Both the UV + PR irradiated cultures were then allowed to progress to mitosis where samples of cells were collected from the peaks of mitotic activity by colcemid treatments for SCE analysis. Detailed parallel mitotic index curves, such as those of Figure 2, were established to describe the mitotic peaks. (4) The cells were scored and the number of SCEs per cell (Table 2) was determined (± standard error). A control (experiment 1) was established to determine the number of SCEs per cell before exposure to PR light. In experiments 2, 3, 4, and 5, the cells were given a PR fluence of 22,000 J/m^2 from 1 to 4 hours after UV, respectively. The number of SCEs decreased significantly. As the PR time was increased to 5 hours after UV (experiment 6), the photoreactivating capability of the cells appears to be blocked causing the number of SCEs to increase. This phenomenon was apparent through experiment 8, where the PR time was 7 hours after UV. In experiment 9, the number of SCEs began to decrease again (PR time being 8 hours) and this continued until the PR ability of the cells was no longer effective (early S phase). These data demonstrate that the pyrimicine dimers leading to SCEs are photoreactivable in early and late G1 phase, but are not photoreactivable in the middle of G1 phase. The mechanisms associated with this are not known at this time, but this could explain the difference in results that Kato (1974), Wolff (1978), and others obtained.

Table 2. Time course of PR of SCEs induced by irradiation of early G1 phase A87 cells with a UV fluence of 5.0 J/m^2.

Experiment Number*	PR fluence (J/m^2)	PR time (hrs after UV)	Number cells scored	Number SCEs per cell (± standard error)
1	0	0	250	6.25 (±1.21)
2	22,000	1	250	1.90 (±0.15)
3	22,000	2	250	1.83 (±0.16)
4	22,000	3	250	1.95 (±0.10)
5	22,000	4	250	1.75 (±0.09)
6	22,000	5	250	3.10 (±0.46)
7	22,000	6	250	4.90 (±1.02)
8	22,000	7	250	3.65 (±0.64)
9	22,000	8	250	2.35 (±0.21)
10	22,000	9	250	1.90 (±0.11)
11	22,000	10	250	1.88 (±0.10)
12	22,000	11	250	1.95 (±0.10)
13	22,000	12	250	3.85 (±0.44)
14	22,000	13	250	5.30 (±0.93)
15	22,000	14	200	6.15 (±1.16)
16	22,000	16	200	5.95 (±1.01)
17	22,000	20	200	6.40 (±1.22)
18	22,000	30	200	6.20 (±1.30)

* Synchronous cultures, unifiliarly labelled with BrdU, were exposed to UV one hour after mitotic selections. The mitotic indices of these cultures at the beginning of the experiments were greater than 0.97.

Table 3. Time course of PR of lethal lesions induced by irradiation of early G1 phase A87 cells with a UV fluence of 5.0 J/m^2.

Experiment Number*	PR fluence (J/m^2)	PR time (hrs after UV)	Number cells plated	Normalized surviving fraction (± standard error)
1	0	0	3,000	0.180 (±0.002)
2	22,000	0.5	3,000	0.940 (±0.014)
3	22,000	1.0	3,000	0.900 (±0.015)
4	22,000	1.5	3,000	0.880 (±0.003)
5	22,000	2.0	3,000	0.712 (±0.002)
6	22,000	2.5	3,000	0.650 (±0.001)
7	22,000	3.0	3,000	0.570 (±0.001)
8	22,000	3.5	3,000	0.475 (±0.002)
9	22,000	4.0	3,000	0.360 (±0.001)
10	22,000	4.5	3,000	0.280 (±0.001)
11	22,000	5.0	3,000	0.210 (±0.002)
12	22,000	5.5	3,000	0.179 (±0.001)
13	22,000	6.0	3,000	0.182 (±0.001)
14	22,000	7.0	3,000	0.175 (±0.001)
15	22,000	8.0	3,000	0.191 (±0.001)
16	22,000	9.0	3,000	0.180 (±0.001)
17	22,000	10.0	3,000	0.182 (±0.002)
18	22,000	12.0	3,000	0.177 (±0.001)
19	22,000	15.0	3,000	0.178 (±0.001)
20	22,000	20.0	3,000	0.183 (±0.002)

* Early G1 phase cells (unifiliarly labelled with BrdU) were exposed to UV one hour after mitotic selection.

Data from the time course of PR of lethal lesions experiments are depicted in Table 3. These experiments consisted of essentially the same four steps as was used for the time course of PR of SCEs experiments (Table 2), except the normalized surviving fraction (instead of the number of SCEs) was determined. Experiment number 1 (control) shows the surviving fraction to be 0.180 without the application of PR. In experiment number 2, PR was introduced 0.5 hours after UV and the surviving fraction increased significantly (to 0.940). PR was continually administered at specific times after UV and the surviving fraction was determined as shown in Table 3. The surviving fraction continued to decrease up to PR time 5.5 hours after UV. At this point, the pyrimidine dimers associated with lethal killing appear to be no longer photoreactivable. As the PR

time after UV was increased, the ability of the cells to photoreactivate continually dropped. This coupled with the data from Table 2 shows that the kinetics associated with PLLs are different from the kinetics associated with PSCEs, demonstrating that PSCEs constitute few, if any, lethal lesions. Plotting the fraction of maximum PR of SCEs against the fraction of maximum PR of lethal lesions (Figure 4) clearly indicates that the set of PPDs expressed as PSCEs are not identical with the set expressed as PLLs and implies that (1) the mechanisms associated with SCE induction are different from those associated with lethal lesions, and (2) further research should be attempted in this area to explain why the photoreactability of SCEs is blocked in the middle of G1.

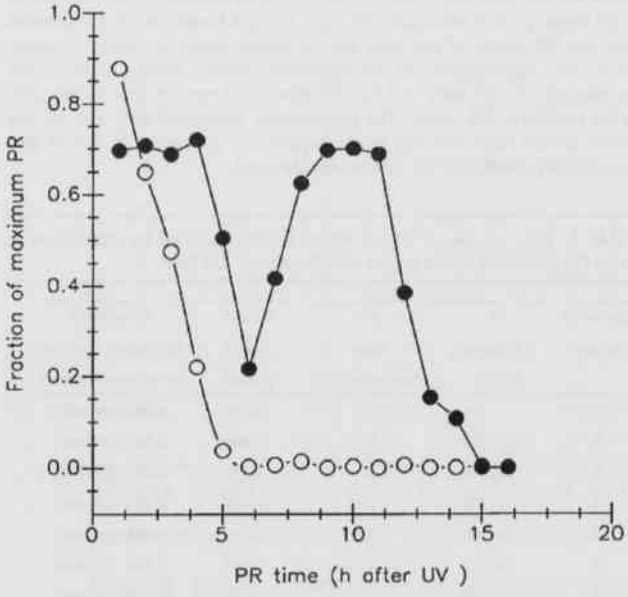

Figure 4. Time course curves showing how the fraction of maximum PR of UV-induced SCEs (filled circles) differs from the fraction of maximum PR of UV-induced lethal lesions (open circles) as the cells progress through G1 phase into S phase. The curves clearly indicate that the sets of PPds associated with each are not identical.

In conclusion, the experimentation described here indicates that a substantial fraction of the SCEs induced in early G1 phase A87 cells by UV are PSCEs and, thus, result from intracellular expression of pyrimidine dimers induced by the UV. Relatively few, if any, of these PSCEs constitute PLLs. This experimentation also suggests that, additional high resolution cytological studies of this nature may yield further interesting correlations between radiation repair mechanisms, changes in chromatin structure, and organization as cells progress through the cell cycle.

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ANN: A SET OF EDUCATIONAL NEURAL NET SIMULATORS

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ABSTRACT

ANN has been developed on MS-DOS computers primarily for educational uses. Currently, it consists of six simulation programs. ANN1 is a very simple neural net which shows how a network learns by adjusting its connection weights. ANN2 is a single processing element neural net, in which the user trains the network manually by adjusting the connection weights and the threshold value. ANN3 is a manually trained simple two layered network. It demonstrates the power of hidden neurons. ANN4 is a Bidirectional Associative Memory network. ANN5 is a Perceptron that learns from examples. ANN6 is a network based on the backpropagation of error. Graphics have been used extensively in all networks. Students can observe the way these networks learn. Hypertext is used to explain concepts, and also serves as an online user's manual.

INTRODUCTION

Artificial neural networks have become very popular in the past few years. A fascinating feature of a neural network is its ability to learn. Several network models and various training algorithms have been developed and utilized successfully in many applications (Simpson, 1990). Many schools have offered formal courses on the subject. To transfer this technology to students, hands-on simulators are needed to demonstrate concepts. At present, there are several commercial software simulators. These software packages are expensive, are too complex for class uses, and are not designed for educational purposes. There are also several public-domain simulators, which are normally specific to one particular network model and are generally not sufficiently documented.

ANN has been developed with students in mind. It runs on an MS-DOS computer with EGA or higher resolution graphics, 640-K RAM, and a color monitor. It covers six network models. Students can observe the learning process of these networks. Some networks allow students to train them manually. Graphics have been used extensively in all networks. Hypertext is used to explain concepts and to document the package. This paper describes these networks with emphasis on their educational features. For background information on artificial neural networks and hypertext, books should be consulted, such as a book on neural networks by Wasserman (1989) and a book on hypertext by Shneiderman and Kearsley (1989).

HYPERTEXT MODULE

The objectives of the hypertext module are twofold; to provide explanations of underlining concepts, and to provide an online user's manual. The first prototype (Malasri and Franklin, 1991) was developed using KnowledgePro (Knowledge Garden Inc., 1989), a software tool for expert systems and hypertext development. This tool does not provide useful navigation features, such as path history, index, searching. It is also difficult to update large amounts of textual information with KnowledgePro. Hyperties (Cognetics Corp., 1988) is a software tool designed only for hypertext applications. It guides an author through the authoring process. A programming background is not required. It has been used to develop several courseware packages at Christian Brothers University, and was used to document ANN.

When entering the hypertext module, the "introductory node is displayed. Several links are provided on this node to branch out to other key nodes, including the "network models" node. On the "network models" node, there are several links (ANN1, ANN2, ANN3, ANN4, ANN5, and ANN6). Each link leads to one network model in the ANN package. Fig. 1 shows the "ANN4" node, which provides information on the Bidirectional Associative Memory model, as well as instructions for the ANN4 simulation module. Underlined words are links (on the actual screen, links are highlighted). As shown in Fig. 1, texts are displayed on a background picture. When the "Bidirectional Associative Memory" link in Fig. 1 is selected, additional information is displayed as shown in Fig. 2. On each node, there are several default links that help the user to navigate through the hypertext module. "RETURN TO ..." takes the student back to the previous node. "EXTRA" leads to an "Index" node, where all nodes are listed in alphabetical order. Currently, there are a total of 66 nodes in the hypertext module.

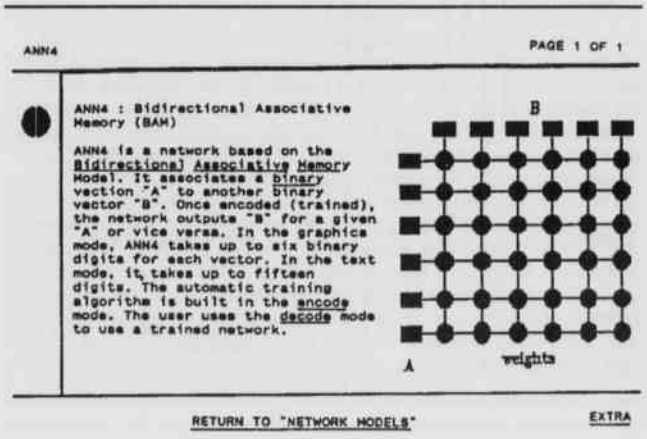

Figure 1. "ANN4" hypertext node.

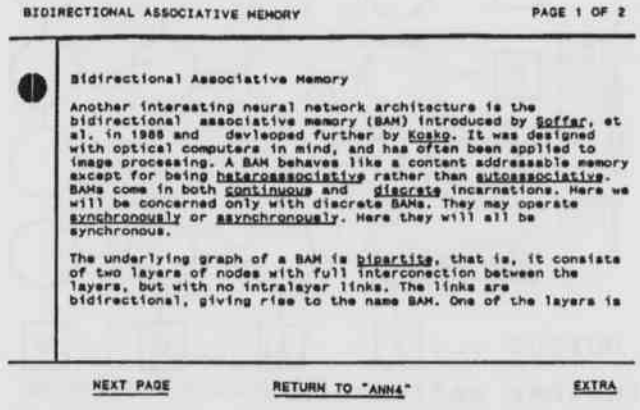

Figure 2. "Bidirectional Associative Memory" hypertext node.

NEURAL NETWORK SIMULATORS

ANN1 – Simple Neural Net

ANN1 is a simple neural network having four input cells fully connected to four output cells. The objective of this module is to introduce the concepts of weighted sum and threshold. Table 1 summarizes data for sample runs of all networks discussed in this paper. For ANN1 the sample run consists of four training pairs (Allman, 1989). Fig. 3 shows a sample screen of the input mode. The circles represent connection strengths (weights). Once the student enters a training pair consisting of an input vector and a target output vector, the network learns by adjusting its connection weights. A weight changes from zero to one when both input and output cells have values of 1. The network recalls by comparing the weighted sum with the threshold, as shown in Fig. 4. If the weighted sum if greater than or equal to this threshold, the output is set to "1"; otherwise the output is set to "0" (zero). The student can change the threshold, which is initially set to zero, until the desired output is obtained. This network may not recall all training pairs.

Table 1. Data for Sample Runs.

Network	Input	Output	Other training parameters
ANN1	1 0 1 0	1 1 0 0	
	0 1 0 1	0 0 1 1	
	1 1 0 0	1 0 0 1	
	0 0 1 1	0 1 1 0	
ANN2	1 1	1	
	1 0	1	
	0 1	1	
	0 0	0	
ANN3	1 1	0	
	1 0	1	
	0 1	1	
	0 0	0	
ANN4	1 0 1 0 1 1	1 1 0 1	
	1 1 1 0 0 1	1 0 1 1	
	1 0 0 1 1 0	0 1 1 0	
ANN5	1 1 1 1 1	1	Learning rate coef. = 1
	1 1-1 1-1	0	
	0 1 1 1 1	1	
	1 1-1-1 1	0	
	-1 1 1-1 1	1	
ANN6	1 1	0	Learning rate coef. = 0.9
	1 0	1	Momentum coef. = 0.9
	0 1	1	Accuracy = 0.1
	0 0	0	

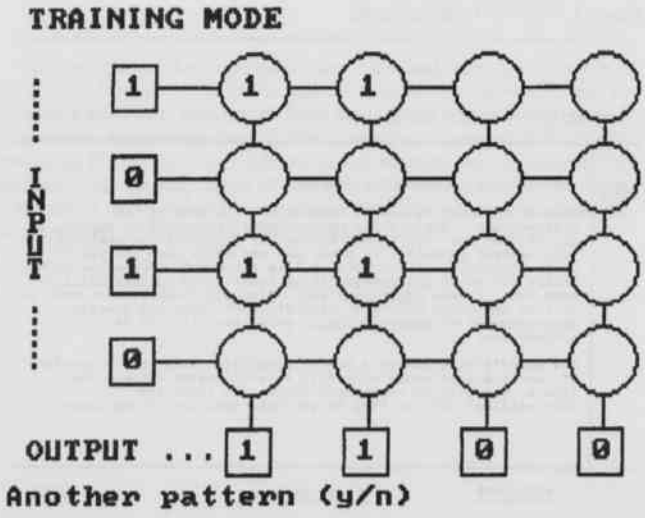

Figure 3. Training mode of ANN1.

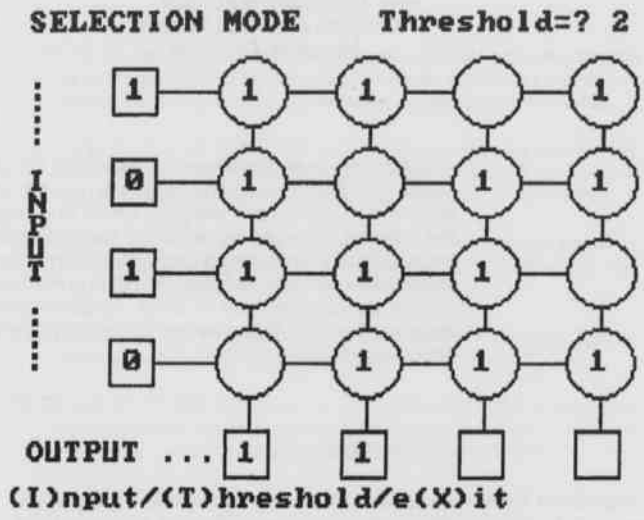

Figure 4. Selection (recall) model of ANN1.

ANN2 – Simple Perceptron

ANN2 produces a single processing element neural network, which allows two binary digits of input and one binary digit of output. The objective of this module is similar to that of ANN1; to demonstrate the concepts of connection weights, weighted sum, and threshold. The weights are, however, not limited to "0" and "1" as in ANN1. A set of training pairs is shown in Table 1. After entering a training pair, the user manually adjusts the connection weights and threshold until the desired output is obtained, as shown in Fig. 5. To be solved by ANN2, the problem must be linear separable. The classic "Exclusive OR" problem cannot be solved with this model.

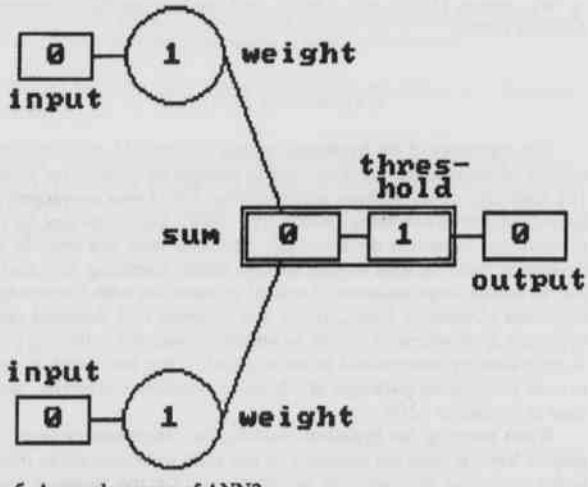

Figure 5. A sample screen of ANN2.

ANN 3 – Simple Multiple Layered Network

ANN3 creates a network with one hidden layer. It has two input neurons (cells), two hidden neurons, and one output neuron. The objective is

to demonstrate the power of hidden cells. This network is capable of solving the "Exclusive OR" or "XOR" problem, as shown in Table 1. The user can adjust connection weights, as well as the threshold values until all input vectors produce desired output. Fig. 6 shows a sample screen of this network.

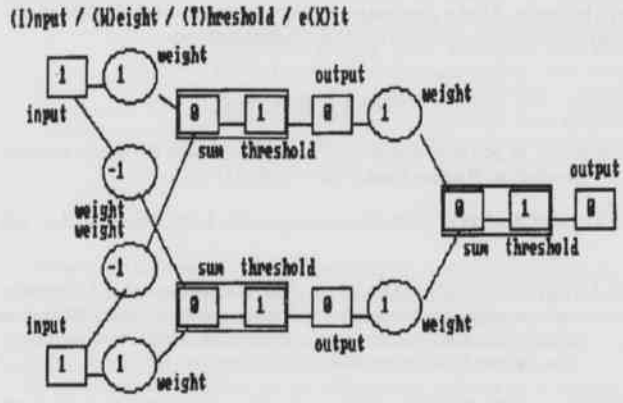

Figure 6. A sample screen of ANN3.

ANN4 – Bidirectional Associative Memory

ANN4 is based on the Bidirectional Associate Memory model. There are two modes: graphic mode and text mode. In the graphic mode, the user observes the changes of weights during a training (encoding) session through the network configuration shown in Fig. 7. Due to the screen display constraint, only six binary digits are allowed for input and output. In the text mode, the number increases to fifteen binary digits for input and output since only matrices of numbers are displayed. The learning process is taken from a textbook (Soucek and Soucek, 1988).

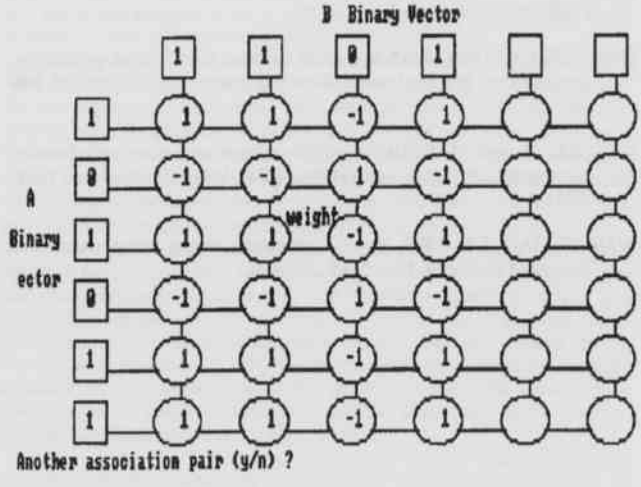

Figure 7. Encoding mode of ANN4.

Fig. 8 shows a recall process, which the vector B can be recalled from the given vector A or vice versa. The user can let the flow go back and forth in both directions until the system converges. Fortunately, this model always rapidly converges, and will not oscillate (Kosko, 1987).

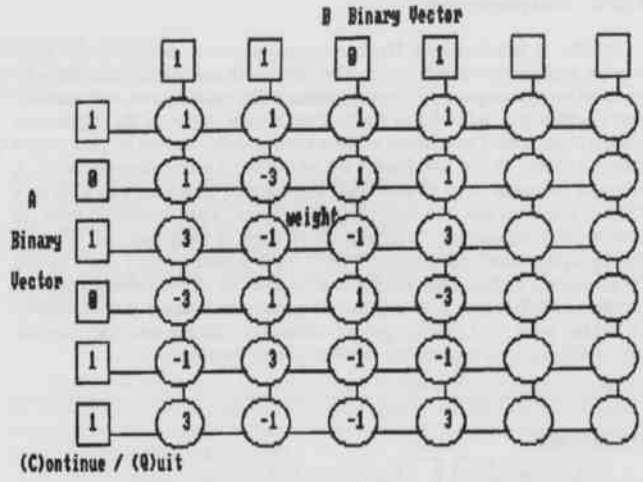

Figure 8. Decoding mode of ANN4.

ANN5 – Threshold Logic Unit

ANN5 provides a single processing element network, similar to ANN2. It, however, allows up to seven binary digits for input as shown in Fig. 9. An automatic learning process is built-in, so that there is no need for a trail-error process as in ANN2. The objectives are to introduce the concept of Hebbian learning rule, delta rule, and learning rate coefficient. "Slow" mode allows the user to observe the weight changes for each cycle. "Fast" mode displays the weights after each cycle continuously. "Bias", an additional input that always has the value of 1, is added to the processing element to speed up the training time. The training process implemented in ANN5 follows an algorithm appearing in a textbook (Soucek and Soucek, 1988). In this process, the weights are adjusted in proportion to the input with the user's specified training rate coefficient. When the training starts, all weights are set to zero. Weights are then adjusted in each cycle until desired output is obtained for all pairs. The recall process uses a similar graphic screen, as previously shown in Fig. 9, with the "desired output" box omitted.

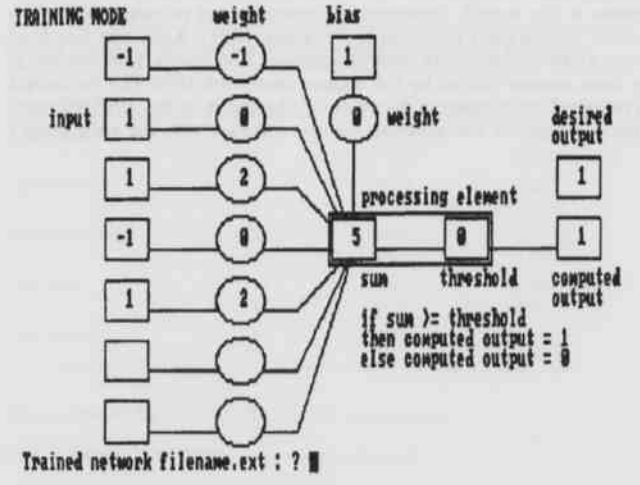

Figure 9. ANN5 network configuration.

ANN6 – Backpropagation

ANN6 is based on the Backpropagation model, which is the most popular architecture in use today. The objectives are to introduce the concepts of backpropagation of error, hidden cells, training rate and momentum coefficients. ANN6 has up to four binary digits of the input, one hidden layer with a maximum of four hidden cells, and up to four output cells, as shown in Fig. 10. Biases are added to all processing elements. A sigmoid function is used to obtain the output. The user can choose a "Slow" mode to see one cycle at a time or a "Fast" mode to have all cycles run continuously. The algorithm used is based on the "Vanilla Backpropagation" (Simpson, 1990) with a momentum term added (Wasserman, 1989). This model can be used to solve several practical problems. Difficulties with this model include choosing a proper number of hidden cells and finding proper values for training rate and momentum coefficients. It sometimes requires a long training time.

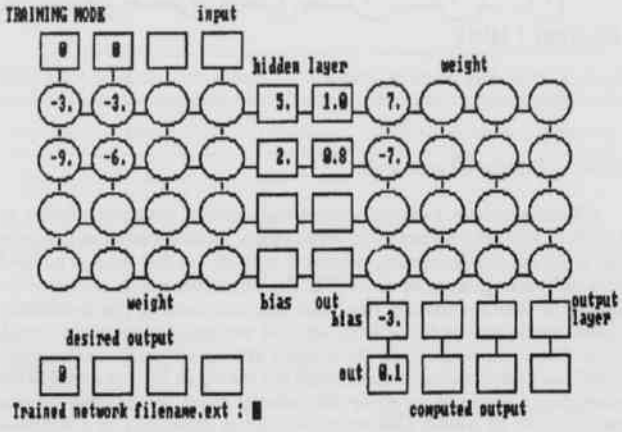

Figure 10. ANN6 network configuration.

CONCLUSION

This paper briefly describes each network model in the ANN package. In order to use the software effectively, a set of well-planned assignments is also equally important. At present, some of these assignments are in printed form (Franklin and Malasri, 1991). ANN was first used with 19 faculty members from 18 academic institutions, who enrolled in a short course offered by the authors under the 1990-91 Chautauqua Program. One question in the course evaluation is on the ANN software. Each participant was asked to rate the software with the scale from 1 (poor) to 5 (excellent). The average rating was 4.43. We are very encouraged with this result. Several other network models are being developed and will be added to the package. The next version will be tested with a graduate class on "Knowledge Engineering" under the Engineering Management Program at Christian Brothers University, which covers expert systems. hypertext, and artificial neural networks (Malasri *et al.*, 1992). At that time, more extensive evaluation on the hypertext modules will be made. After a few years, we hope to cover most of popular network models with extensive hypertext documentation.

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PHOTOSYNTHETIC EFFICIENCY OF DROUGHT-INDUCED LEAVES IN *NEVIUSIA ALABAMENSIS*

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ABSTRACT

Plants in one stand of *Neviusia alabamensis* Gray (Rosaceae), a rare shrub, became drought deciduous in July, 1990, and grew new leaves following rains in August. In September the photosynthetic efficiency of the new leaves was compared with that of old leaves in another stand of the same population. Although leaf area from regrowth was much less than old leaf area retained, photosynthetic efficiency in new leaves was about 3 times higher than in old leaves. This response is discussed in terms of compensation for drought-induced loss of leaves.

INTRODUCTION

"*Neviusia alabamensis* Gray (Rosaceae) is a perennial shrub with numerous slender primary stems and short lateral branches. The bright green leaves are simple and alternating. The flowers are odorless and lack petals; however, the stamens are numerous (usually over 100) and showy, flowering may occur between March and May" (Long, 1983).

N. alabamensis is listed as an endangered species in Arkansas, Alabama and Missouri, and has only recently been discovered in Tennessee and Mississippi. The genus seems to be found only above stream banks in generally dry soils. It appears to be capable of reproducing only by root sprouts (Long, 1983).

The two sites at which this study took place are the east and west ends of the Conway County, Arkansas population. This population extends along a southeast-facing ridge above Cadron Creek between Conway and Menifee, Arkansas. The population is separated into two colonies by 100 meters of forest (Long, 1989). The plants at these two sites are possibly all one genet (Freiley, pers. comm.). There are only three other known populations in Arkansas.

Since *N. alabamensis* is mostly found in dry conditions, the strategies to deal with water stress must be an important part of the plant's ability to survive. In September 1990, plants in sites only 100 meters apart were observed to be in strikingly different condition following summer drought. Plants at the east Conway County site, site 1, retained the original leaves produced in spring while the plants at the west Conway County site, site 2, had dropped most of these mature leaves and, following several weeks of rain, had grown new leaves.

Plants growing in different environments have leaves of characteristic sizes and shapes. According to Townsend and Solbrig (1980), for example, tree leaves in the temperate zone are normally of moderate size with toothed or serrated margins; evergreen plants from warm semidesert regions have smaller leaves, sub-canopy tropical trees have very large leaves with entire margins and pointed apices; and many trees in tropical and subtropical savannas have compound leaves. Even on the same tree, leaves exposed to the sun tend to be smaller than those in the shade.

Leaves are the main biochemical factories of the plant, intercepting light and transforming that energy to fix CO_2 and synthesize sugars. The leaf needs adequate light, ample raw materials, plenty of water, and appropriate temperatures to function effectively. Securing these conditions presents difficulties to the plant, considering, among other things, that for every molecule of CO_2 that is fixed, anywhere from 300 to 1000 molecules of H_2O vapor are lost. The adaptive problem the plant faces is how to maintain adequate water and nutrients while maximizing net photosynthesis (Townsend and Solbrig, 1980).

Plant species can maintain physiological activity during periods of drought through a variety of mechanisms. These mechanisms can be grouped as avoidance or tolerance of drought. One avoidance strategy, conversion to a dormant phase, becomes more important as environmental moisture stress becomes increasingly severe (Chabot and Bunce, 1979).

"Plants grow by the progressive accumulation of repeated elements: leaves, buds, internodes, branches, and flowers" (Maillette, 1985), which together contribute to the particular shape of a plant. In most plants the number of elements is not fixed; it changes with time because of growth and senescence processes. Changes in the number of parts can be caused by demographic events, births, and deaths; plants can be viewed as a population of parts. Because leaves photosynthesize, their demography is of special interest. (Maillette, 1985).

N. alabamensis at sites 1 and 2 responded to drought conditions in two different manners, which were retention, and drop followed by regrowth. Research has shown that the rate of photosynthesis per unit of leaf area typically increases after leaf emergence, reaches an optimum at about the time of full leaf expansion, and then declines (Yamaguchi and Friend, 1979; Catzky and Ticha, 1980; Constable and Rawson, 1980; Bongi *et al.*, 1987; and Nilsen, *et al.*, 1988). This investigation of the effect of leaf age on photosynthesis was designed to consider the strategies of retaining leaves or dropping leaves in *N. alabamensis*.

MATERIALS AND METHODS

Using a portable photosynthesis system, four of the variables used in this report were measured in intact leaves at each site, in September, 1990. At site 1, most plants retained original leaves produced in the spring which had survived the summer drought. For analysis, 130 mature leaves were randomly selected and placed in the chamber of a LI-COR portable photosynthesis system (LI-COR, Inc., Lincoln, NE). After the unit calculated the rates or amounts of net photosynthesis, light intensity, leaf temperature, and CO_2 flow, the leaf was harvested. Each leaf was then traced onto tracing paper and the resulting leaf copy cut out, weighed, and compared to the weight of a known area of tracing paper to determine leaf area in square centimeters. Leaf area data produced the fifth variable considered in this study and were entered into the instrument's computer to produce corrected values of the five (Table 1) variables for each leaf.

Table 1. Analysis of Variance for hypothesis of no overall site effect.

Variable	Site	Mean	Standard Deviation
photosynthesis	1	2.52	1.16**
	2	7.19	3.20**
light intensity	1	731.92	67.08**
	2	337.06	232.16**
leaf temperature	1	29.94	6.39 n.s.
	2	28.60	1.30 n.s.
CO_2 flow	1	357.01	17.38
	2	381.97	20.83
Leaf area	1	12.50	13.77**
	2	4.70	1.27**

Site 1 = Conway East, 130 leaf observations, mature leaves

Site 2 = Conway West, 33 leaf observations, new leaves

** - highly significant, $P < .001$

n.s. - not significant

At site 2, the *N. alabamensis* plants held virtually no original leaves. Within three days of the site 1 analysis, 33 leaves at site 2 were analyzed in the same manner. These leaves were replacements of those abscised during summer drought.

RESULTS

Multivariate analysis of variance (MANOVA) for the hypothesis of no overall site effect revealed a significant difference, ($P < .0001$), between the two sites. Table 1 displays a univariate analysis for the hypothesis of no overall site effect for each variable. The probabilities exhibit significant difference, ($P < .01$), between the two sites for all variables except leaf temperature.

Table 2 displays a stepwise discriminant analysis summary which shows a highly significant difference for three of the five variables, ($P < .001$), and a significant difference for the other two variables, ($P < .05$). This stepwise analysis was performed in order to determine the rank of each variable in terms of predominance. Photosynthesis is shown to explain 54% of the variance between site 1 and 2. Leaf area and light intensity at the time of analysis each account for about 20% of variance between sites. Carbon dioxide and leaf temperature account for little of the variance.

Table 2. Stepwise Discriminant Analysis Summary.

Step	Variable	R^2
1	photosynthesis	.54**
2	leaf area	.205**
3	light intensity	.195**
4	CO^2 flow	.04*
5	leaf temperature	.02*

** - $P < .01$

* - $P < .05$

DISCUSSION

Net photosynthetic rate for the young leaves at site 2 is significantly higher than the net rate at site 1 which is composed of plants with mature leaves. The light during the times of data collection was different, being more intense when measurements were taken at site 1, so the efficiency of photosynthesis in new leaves was accomplished even at significantly lower levels of irradiance. This higher efficiency is probably a factor of the leaf age. Catzky and Ticha (1980) and Constable and Rawson (1980) found net photosynthesis rates to be low in young, unfolding leaves, increasing rapidly as leaves expanded and gradually declining thereafter, reaching low values at senescence. Pasian and Lieth (1989) found no clear pattern in photosynthetic efficiency associated with leaf age, possibly because the study they conducted examined leaves of 10, 20, 30 and 40 days of age. Their study suggested that 10-day-old rose leaves have an almost completely developed photosynthetic mechanism, while senescence does not begin until rose leaves are older than 40 days. According to Bongi (1987), the effect of leaf age on apparent photosynthesis was shown graphically to increase the first 6 months and remain at a level plateau for about 12 months, declining the last 6 months prior to senescence, in olive leaves.

In *Flaveria trinervia*, a C_4 dicot, photosynthesis was found to vary considerably during leaf expansion. In partially expanded leaves (20% of full size), 10-12% of atmospheric CO_2 is assimilated directly by the C_3 pathway while with further leaf expansion, this bypass of the C_4 cycle decreases until the C_4 cycle is fully operational at leaf maturity (Moore and Edwards, 1988).

Bunce (1989) attempted to explain the response of growth rate per unit of ground area, by creating a leaf area index. He found crop growth to show two patterns as leaf area index increases with growth. Growth rate either increased up to a plateau as more light was intercepted or decreased above an optimum leaf area index.

Nilsen *et al.* (1988) studied the changes that occur in leaf structure, such as aging of chloroplats, which eventually causes a decrease in photosynthetic efficiency at some point after leaf maturity. He studied *Rhododendron maximum* L. which is a short flush species producing one cohort of leaves each year so that demographic patterns would be readily identifiable and differences between same age leaves would not be due to growth at different times in the season. They found that photosynthesis rates decreased with increasing leaf age, and decreased more rapidly in light saturated than in low light environments.

Photosynthetic rates of early and late leaves of honey mesquite were measured, exhibiting daily maximum photosynthetic rates of early leaves to be significantly greater than those of late leaves. The higher rates of early leaves were associated with higher nitrogen content per unit leaf area and a thicker leaf blade. (Wan and Sosebee, 1990).

Suzuki *et al.* (1987) suggested the influence of leaf age on photosynthesis rate was due to associated changes with the capacity of the photosynthesis cycle through control of a number of enzyme levels. He did, however, find similar leaf age patterns, reporting, "The rate of photosynthesis per unit area in the third leaf of wheat plants reached a maximum on the seventh day after leaf emergence and then declined to 1/3 of the maximum after 22 days."

For all leaf ages of *Rosa Hybrida* L. ev. *Samantha*, Bozarth *et al.* (1982) found maximum photosynthetic rates were reached at irradiance levels of 450-500 microeinsteins^{-2} sec^{-1}. These rates were highest in the youngest leaves studied and lowest in the oldest. Photorespiration was shown not to be a major factor in this trend.

Tschaplinski *et al.* (1989) studied the physiological basis of reinvigoration after shoot decapitation. "Reinvigoration refers to the renewed vigor of growth and net photosynthesis following decapitation. Defoliation and shoot decapitation are known to increase net photosynthetic rates in the remaining leaves of tree and crop species." Waring *et al.* (1968) and Meidner (1969) also found that an increase in net photosynthesis usually occurs three to four days following shoot decapitation. Partial defoliation which results in an enhancement of photosynthetic rates in the remaining leaves may also occur in rose (Mor and Halevy, 1979). These studies suggest that not only is *N. alabamensis* displaying typical leaf age photosynthetic efficiencies, but it may also be displaying post defoliation reinvigoration.

Most of the studies charting a rise, plateau, and decline in photosynthetic efficiency of leaves as they age are dealing with senescence due to leaf age. Water deficit is also a cause of decline. Vu and Yelenosky (1988) found that water deficit reduced the photosynthetic CO_2 assimilation rate as well as the carboxylation reaction, and the soluble protein content in leaves of citrus trees. Aikin and Hanan (1975) found the net photosynthesis rate in "Forever Yours" rose to increase for the first 8-36 days, and decrease until the leaf is 40-68 days, when the leaf drops. However, internal plant water potential influenced the CO_2 uptake by reducing it at each increase of radiation energy, resulting in lower net photosynthesis with lower water potential.

Therefore it seems that at a certain minimum water potential, *N. alabamensis* plants at site 2 dropped their leaves. When rain brought more water in early fall, the plants were able to sprout new leaves, which exhibited the high photosynthetic efficiency characteristic of their young age as well as reinvigoration following defoliation.

If the population of *N. alabamensis* is a single genet, the differences exhibited in leaf holding may be due to differing soil water holding capacities between sites. Also, it would be interesting to observe over time if the same two strategies of holding versus dropping leaves are predictable after a dry summer and how this affects rate of growth as evidenced by plant biomass between the two sites.

Further study is necessary to make any conclusions as to the long term success of reinvigoration of leaves as a strategy to cope with water stress, in terms of net cost/benefits to the plant. However, regrowth of photosynthetically efficient leaves does extend the growing season for *Neviusia alabamensis*.

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K-SHELL IONIZATION MEASUREMENTS FOR LIGHT INCIDENT IONS

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ABSTRACT

The ionization of the K-shell in targets of copper, silver, dysprosium and gold was investigated with incident ion beams of proton and helium ions in the range 0.5 MeV/u to 3 MeV/u. The x-rays were detected by a HpGe detector. K-shell x-ray production cross section were determined by normalization of the x-ray yield to the incident beam flux, the Rutherford-scattered ions and the nuclear-Coulomb excited gamma ray yield. The multiple normalization procedures minimize the errors in these cross section measurements. The data are compared with the predictions of the ECPSSR theory for K-shell ionization. The atomic number dependence of these K-shell cross section is discussed.

INTRODUCTION

In the interaction of energetic ions with atoms, the inner shell electrons can be excited to higher shells or captured to the bound or continuum states of the projectile. The probability for ionization depends on the atomic numbers of the ion and the target and the energy of the incident ion-beam (Lapicki, 1989). The ionization cross section for a particular shell can be determined from measured yields for the radiative decay mode like the x-ray emission. Knowing the fluorescent yield (Bambynek *et al.*, 1972) for the shell one can convert the x-ray production cross sections into ionization cross sections.

The dominant modes of vacancy production in an ion-atom collision are the direct ionization of the shell (DI) and the electron capture (EC) process. In addition, excitation of the nucleus can lead to ionization of the atom in nuclear decay via e.g. internal conversion processes and other mechanisms. For the K-shell, DI of a target electron to the continuum has been shown to be a principle mode of interaction for $Z_1 << Z_2$ and $v_1 >> v_{2K}$ where Z_1 & Z_2 refer to the projectile ion and the target atomic numbers while v_1 & v_{2K} refer to the incident ion and target K-shell electron velocities, respectively (Merzbacher and Lewis, 1958; Khandelwal *et al.*, 1969; Rice *et al.*, 1977). For $Z_1 \leq Z_2$ and $v_1 \leq v_{2K}$, K-shell electron capture (EC) to bound states of the incident ion is important. The ECPSSR theory (Brandt and Lapicki, 1981) for DI and (Lapicki and McDaniel, 1980) for EC accounts for the energy loss (E) and Coulomb deflection (C) of the incident ion as well as for the Perturbed Stationary States (PSS) and the Relativistic nature (R) of the inner shell electrons. The ranges of Z_1/Z_2 and v_1/v_{2K} parameters investigated were $0.012 < Z_1/Z_2 < 0.069$ and $0.05 < v_1/v_{2K} < 0.24$, respectively.

The measurement of ionization by measuring the x-rays involves normalizing the x-ray yields to simultaneously measured other quantities that pertain to the same ion-atom interaction. These variable quantities have error involved in their measurements. A variety of normalization variables allow one to determine and report the x-ray production cross sections with greater precision. The experimentally measured cross sections can be compared with the prediction of the existing theories (Lapicki, 1989) and conclusions can be drawn regarding the validity of the theories and the accuracy of the measurements.

In the present experiment the beam of protons or helium ions were produced by the East Carolina University 2MV Tandem Van de Graaff accelerator. Thin targets of copper, silver, dysprosium (natural and enriched) and gold were produced by vacuum evaporation of the elements on thin carbon substrates. The K-shell x-rays and other photons produced in the ion-atom collision were detected and measured with a HpGe detector that had a resolution of 195 eV at 5.9 keV and 488 eV at 122 keV. The K-shell x-ray energies ranged from 8.0 keV for copper K_α to about 68 keV for K_α for gold targets. Rutherford scattered ions were measured with a silicon surface barrier detector. More details of the experimental procedure, the scattering chamber setup and analysis of the data are given elsewhere (Bissinger *et al.*, 1989; Mehta *et al.*, 1991).

The 43.8 keV gamma ray excited in the dysprosium targets (due to the presence of the ^{161}Dy isotope) was measured together with the K-shell x-rays of dysprosium and was later used to normalize the K-shell x-ray production cross section (Celler *et al.*, 1979) through the accurately known cross section for gamma ray production (Brown *et al.*, 1978). In addition the relative detector efficiency was also established through these gamma ray measurements. The K-shell x-ray production cross sections, σ_{KX}, were obtained using the following equations:

$$\sigma_{KX} = [\, Y_X / \varepsilon\, n_0\, n_1 \,] \quad \ldots\ldots (1)$$
$$\sigma_{KX} = [\, Y_X / \varepsilon \,]\, [\, \sigma_R\ \Omega / Y_R \,] \quad \ldots\ldots (2)$$
$$\sigma_{KX} = [\, Y_X / \varepsilon \,]\, [\, \sigma_\gamma \varepsilon_\gamma / Y\gamma \,] \quad \ldots\ldots (3)$$

where Y_X is the K x-ray yield, ε and ε_γ are the efficiency of the HpGe detector at the K x-ray energy and the 43.8 keV gamma rays, respectively, n_0 is the target thickness in atoms/cm^2, n_1 is the beam flux (determined from Q, the charge collected in the Faraday cup), σ_R and σ_γ are the cross section for Rutherford scattering and 43.8 keV gamma ray emission, respectively, Ω is the solid angle subtended by the silicon surface barrier particle detector, Y_R and Y_γ are the Rutherford scattered particle yield and the 43.8 keV gamma ray yield, respectively. Equation (3) was used only for the dysprosium targets and the percentage of ^{161}Dy in the target was employed in these computations.

RESULTS AND DISCUSSION

In Figure 1, the K-shell x-ray production cross section, σ_{KX}, in barns

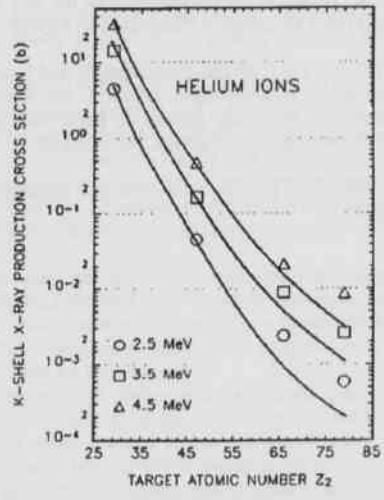

Figure 1. K-shell x-ray production cross section in barns, σ_{KX}, versus the target atomic number Z_2 for incident helium ions at 2.5 (circle), 3.5 (square) and 4.5 (triangle) MeV. The cross section scale is in powers of ten. The three solid curves represent the prediction of the ECPSSR theory in order of increasing energy e.g. the lowest solid curve is for 2.5 MeV helium ions.

is plotted versus the target atomic number Z_2 for incident ^4He ions at energies of 2.5, 3.5 and 4.5 MeV. The cross sections decrease with increasing atomic number of the target. Going from copper to gold targets, at identical beam energy this decrease is dramatically large (by a factor of ~2000 or more). Also this decrease is greater for higher energy helium ion beam. In other words the cross section for incident helium ion beam in the energy range shown here are greatest for the lowest atomic number target (Z_2=29) at the highest beam energy (4.5 MeV).

In Figure 2, the K-shell x-ray production cross section, σ_{KX}, in barns are plotted versus the target atomic number for proton and helium ion beam, both at identical energy per unit mass of 1.0 MeV/u representing identical velocity ions. Again for each ion beam a dramatic decrease in cross section is seen with increasing Z_2. The stronger nature of the decrease in the cross sections for the helium ions over those for the protons is evident in the larger slope among the open squares. The larger cross section for the helium ion over those for the proton beam for a particular target is because of the larger atomic number of the helium ion over that of a proton.

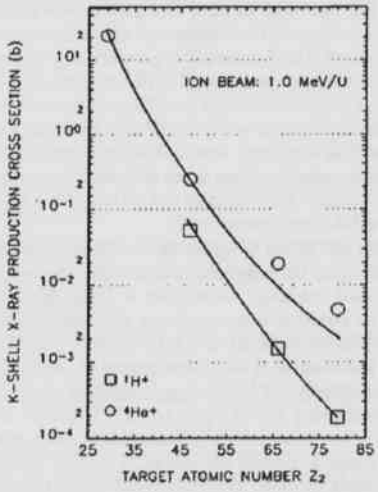

Figure 2. K-shell x-ray production cross section in barns, σ_{KX}, versus the target atomic number Z_2 for identical velocity proton and helium ions. The symbols circle and square represent the helium and the hydrogen ion data, respectively. The solid curve portrays the predictions of the ECPSSR theory. The upper curve is for helium and lower for proton beam.

In Figures 1 and 2, the solid curves representing the prediction of the ECPSSR theory (Lapicki, 1989) shows good agreement with the measured cross sections. The theory accurately predicts the trend in these cross sections as discussed in previous paragraphs. The agreement ranges from excellent for proton data for all the elements and silver in the helium data studied here and fair to poor for helium data for dysprosium and gold. As discussed (Bissinger *et al.*, 1989) for the dysprosium targets a complex correction needs to be made to account for the internal conversion contributions to the inner-shell vacancy production.

The largest error in these measurements comes from the error in the determination of the efficiency of the detector (Mehta *et al.*, 1991). The multiple normalization techniques using equations (1)-(3) reduce the error in these cross sections (Bevington, 1969) and provides a cross check for the consistency among these normalization procedures.

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EVALUATION OF *APOSPHAERIA AMARANTHI* AS A BIOHERBICIDE FOR PIGWEED (*AMARANTHUS* SPP.).

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ABSTRACT

Studies were conducted to determine the potential of the fungus, *Aposphaeria amaranthi,* as a bioherbicide for pigweeds (*Amaranthus* spp.). Experiments to establish the environmental parameters necessary for control of tumble pigweed *(A. albus)* demonstrated that an 8-hr dew period was sufficient for control of seedlings with four to six leaves, and that temperatures ranging from 20 to 28 C were conducive for disease development. Conidial concentrations as low as 1 x 10^5 conidia per ml also were sufficient for plant mortality. Host range tests demonstrated pathogenicity of *A. amaranthi* to several other species of *Amaranthus,* including biotypes resistant to triazine herbicides. Disease on redroot pigweed *(A. retroflexus)* was enhanced by incorporation of surfactants into inoculum suspensions. Field tests conducted in1990 resulted in 73% control of redroot pigweed and 99% control of tumble pigweed. These results suggest that *Aposphaeria amaranthi* has potential as a bioherbicide for controlling pigweeds.

INTRODUCTION

Since 1965 more than 250 million acres in the United States have been treated annually with chemical herbicides (Hill, 1982). While chemicals are effective for controlling weeds, their tremendous usage has had undesirable side-effects as well, including residual carry-over (McWhorter and Chandler, 1982), build-up of resistant weed biotypes (Vencill and Foy, 1988), and detrimental effects on the environment. An alternative method for controlling weeds is the use of mycoherbicides, in which fungi are applied inundatively to control or reduce target weed populations (Templeton and Smith, 1977).

The genus *Amaranthus* includes over 60 species, of which the majority are considered weeds, commonly referred to as pigweeds (Ruskin, 1984). Many pigweed species are serious or principal weeds in major crops (Feltner, 1970). Some species have developed biotypes which are genetically resistant to chemical herbicides (Ahrens *et al.,* 1981) and others have been implicated in livestock poisoning, due to high nitrate levels (Holm *et al.,* 1977). In 1987, *Aposphaeria amaranthi* Ell. & Barth., a pycnidial Coelomycete, was isolated from a diseased *Amaranthus* L. species collected at the University of Arkansas Agricultural Experiment Station, Fayetteville. Preliminary host range tests demonstrated pathogenicity of *A. amaranthi* to several *Amaranthus* spp. *Amaranthus albus* L., commonly known as tumble pigweed, was found to be most susceptible. Further studies were conducted to determine the potential of *Aposphaeria amaranthi* as a bioherbicide for pigweed.

MATERIALS AND METHODS

Aposphaeria amaranthi was isolated from symptomatic plant tissues surface disinfested in 1% sodium hypochlorite for 30 sec, rinsed in sterile water for 60 sec, transferred to potato dextrose agar (PDA) (Tuite, 1969) amended with 0.3 mg per ml streptomycin sulfate and incubated at room temperature. Sporulating isolates were stored at -80 °C. Inoculum was prepared by subculturing the fungus on pea juice agar (PJA) (Weidemann *et al.,* 1988) from cultures in cryogenic storage. Cultures were incubated under fluorescent lights (12-hr photoperiod) at 24 to 26 °C for four to six days. Conidia were rinsed from the plates with distilled water and strained through a 1-mm mesh screen. Desired concentrations were standardized using a hemacytometer.

Plants were grown from seed in 28 °C growth chambers (14-hr photoperiod, 330 µE/m2/s). Seedlings were spray inoculated to run-off with conidial suspensions of 1-2 x 10^6 conidia per ml 3 wk after planting, at the four- to six-leaf stage. After the dew period, plants were returned to the 28 °C growth chamber.

Disease severity and plant mortality were determined two and ten days after inoculation. Each treatment consisted of at least three replicated pots with three to five plants. Experiments were repeated at least twice. Controls for each experiment consisted of two pots sprayed with distilled water. Six pots with three to five plants each were used for each species in the host range tests. Assessment of disease severity was based on a rating system of 0 to 5, where 0 = no visible symptoms, 1 = 1-25% necrosis, 2 = 26-50% necrosis, 3 = 51-75% necrosis, 4 = 76-99% necrosis, and 5 = plant death. Inoculated seedlings in the host range tests that showed no visible symptoms were considered immune. Plants that averaged a rating of less than one were considered resistant, and all others were considered susceptible. Data were subjected to analysis of variance and treatment means were compared using the Least Significant Difference at the 5% significance level.

To determine the effect of plant age on disease severity, seedlings were inoculated from the cotyledon stage until axillary buds began to develop. Inoculated seedlings were given a 24-hr dew period at 28 °C. The influence of conidial concentrations was determined by spraying plants with conidial suspensions of 1 x 10^4, 1 x 10^5, 1 x 10^6, and 1 x 10^7 conidia per ml followed by a 12-hr dew period at 28 °C. The dew period requirement was determined by placing inoculated plants in a 28 °C dew chamber and transferring sets of 4 pots to a 28 °C growth chamber after 4, 8, 12, and 24 hr. To determine the effect of dew temperature, inoculated seedlings were given 24-hr dew periods at 20, 24, 28, and 32 °C.

Host range tests included common weed species of *Amaranthus,* as well as triazine-resistant biotypes, and species used as ornamentals and as grain crops. Tests also were conducted on other genera within the Amaranthaceae and on representive genera of related families. Seedlings in the host range tests were given a 24-hr dew period at 28 °C after inoculation with conidial suspensions of *Aposphaeria amaranthi* at 1-2 x 10^6 conidia per ml. Replicated pots of triazine-resistant biotypes of *Amaranthus hybridus* (smooth pigweed) also were sprayed with atrazine [6-chloro-N-ethyl-N'-(1-methylethyl)-1,3,5-triazine-2-4-diamine)], at the recommended field rate of 1.3 mg per 100 ml.

To enhance pathogenicity of *A. amaranthi* on *A. retroflexus* (redroot pigweed), activate plus (Riverside/Terra Corp., Sioux City, IA), agri-dex (Helena Chemical Co., Memphis, TN), soydex (Setre Chemical Co., Memphis, TN), and Mazola corn oil (Best Foods, Inc., Englewood Cliffs, NJ) were incorporated at 0.5% into separate inoculum suspensions of *Aposphaeria amaranthi* at 1-2 x 10^6 conidia per ml and given a 12-hr dew period at 28 °C following inoculations.

Field plots, 0.5 x 2 m, separated by 1.5 m alleys, were established at the University of Arkansas Agricultural Experiment Station, Fayetteville in 1990. Plots were seeded on June 5 with one row of tumble pigweed and one row of redroot pigweed. The test was arranged as a randomized complete block with five replications.

Inoculum for the field study was prepared as previously described and adjusted to 1 x 10^6 conidia per ml and 6 x 10^6 conidia per ml. Treatments were applied on June 22 to plants with two to six leaves. Applications were made at 280 L/ha (30 gpa), 1000 L/ha (100 gpa), and to run-off (1400 L/ha) using a CO_2 backpack sprayer equipped with a single boom flat spray tip nozzle (Teejet 8003) at 20 psi, and with a pump sprayer for plants sprayed to run-off.

RESULTS

Seedlings of tumble pigweed with up to eight leaves were readily killed by *A. amaranthi*. Once plants began developing axillary buds (12 to 14 leaves) disease development decreased and symptoms primarily consisted of restricted stem and leaf lesions. Conidial suspensions of 1 x 10^5 to 1 x 10^7 conidia per ml were sufficient for 100% mortality of tumble pigweed seedlings. When concentrations were decreased to 1 x 10^4 conidia per ml only 75% of the seedlings were killed. Only an 8-hr dew period was necessary for plant death (Table 1), and dew temperatures ranging from 20 to 28 °C were conducive for disease development (Table 2).

Table 1. Effect of dew period on disease severity and mortality of tumble pigweed seedlings 10 days after inoculation with *A. amaranthi* at a concentration of 1-2 x 10^6 conidia/ml at 28 °C.[x]

Dew period duration (hr)	Disease severity[y]	Mortality (%)
4	2.7a	30a
8	5.0b	100b
12	5.0b	100b
24	5.0b	100b

[x]Seedlings (four- to six-leaf stage) were spray inoculated with conidial concentrations of 2 x 10^6 conidia per ml and given dew periods at 28 °C.

[y]Disease severity rating: 0= no visible symptoms, 1= less than 25% necrosis, 2= 26-50% necrosis, 3= 51-75% necrosis, 4= 76-99% necrosis, 5= plant death.

[z]Values followed by the same letter in the same coluan are not significantly different using LSD (P= 0.05).

Table 2. Effect of dew temperature on disease of tumble pigweed seedlings 10 days after inoculation with *A. amaranthi* at a concentration of 1-2 x 10^6 conidia/ml and given a 24 hr dew period.

Dew temperature (C)	Disease severity(y)	Mortality (%)
20	5.0a(z)	100
24	5.0a	100
28	5.0a	100
32	1.8b	0

(y)Disease severity rating: 0= no visible symptoms, 1= less than 25% necrosis, 2= 26-5-% necrosis, 3= 51-75% necrosis, 4= 76-99% necrosis, 5= plant death

(z)Means followed by the same letter in the same column are not significantly different at P= 0.05, according to Duncan's multiple range test

Host range tests demonstrated that with the exception of *Acnidia altissme*, disease incited by *A. amaranthi* was limited to the genus, *Amaranthus*. Plants outside the Amaranthaceae were immune. The majority of *Amaranthus* species, including weeds, ornamentals, and species used as grain crops were susceptible to *Aposphaeria amaranthi*. Biotypes of *Amaranthus* resistant to triazine herbicides also were susceptible.

In growth chamber studies mortality of redroot pigweed seedlings was increased from 33% for plants sprayed with the fungus alone to 93% for plants sprayed with the incorporation of surfactants into inoculum suspensions and given a 12-hr dew period.

Field tests resulted in 73% control of redroot pigweed and 99% control of tumble pigweed when plants were sprayed to run-off with conidial suspensions of 6 x 10^6 conidia per ml. Lower conidial concentrations or application rates were not as effective.

DISCUSSION

Laboratory and field studies demonstrated that *A. amaranthi* is an effective biological control for tumble pigweed. Seedlings with four to six leaves were killed at temperatures ranging from 20 to 28 °C and with conidial concentrations as low as 1 x 10^5 conidia per ml. The dew period requirement necessary for plant death was considerably lower than the dew period required by most fungi investigated as potential bioherbicides. Applications made shortly after emergence probably would be most effective since mortality decreases with plant age and with temperatures above 28 °C.

Effective control levels of redroot pigweed were achieved in field tests only with a combination of high conidial concentrations and high application rates. Growth chamber studies, however, indicated that mortality of redroot pigweed could be increased with incorporation of surfactants into inoculum suspensions. Results from host range tests suggest that *A. amaranthi* is restricted to the Amaranthaceae and would pose little threat to non-target plants. These results suggest that *Aposphaeria amaranthi* has potential as a bioherbicide for pigweed.

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A SIMPLE SYNCHRONOUS DETECTOR FOR SPECTROSCOPIC STUDIES

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ABSTRACT

Lock-in-amplifiers are used in many applications for signal processing and offer the ability to discriminate high levels of noise. While these instruments are very powerful and offer many features, they are not portable and are expensive. An economical and easy to use alternative circuit is presented which incorporates pre-amplification, reference, and synchronous detection on one circuit board. The design can be used in laboratory or process control situations where its small size and low cost are advantageous. The circuit was successfully applied to moderate and high level signals as seen in flame infrared emission detection and in a portable radiometer for rocket plume studies.

INTRODUCTION

One of the principal methods of enhancing a small and narrow band signal is to use electronic hardware devices, filters, and/or modulation and demodulation. If the signal and noise cannot be separated by filtering alone, it is then best to carry out a modulation/demodulation step. Modulation is accomplished by transposing the signal onto a carrier wave with the desired frequency. The resultant signal is amplified and then goes through a demodulation (or reverse modulation) step, in which the original signal is recovered from the carrier wave. A lock-in-amplifier (LIA) is a signal measurement and processing system that is very efficient in discriminating against the noise components of a signal. It works by synchronizing the modulation and demodulation steps on a carrier signal. Since the desired signal information is contained within the carrier, the non-carrier related components such as flicker noise, hum and other interferences are rejected. An LIAcan form an extremely narrow bandpass filter that automatically centers on the frequency of interest and can yield tremendous improvements in signal to noise ratios. In practice, lock-in-amplifiers can extract a signal 120 dB below the noise level.

Investigations of infrared emissions from combustion flames and related sources have been carried out using lock-in-amplifiers (Hudson and Busch, 1987; 1988) (Hudson *et al.*, 1990). While these instruments are very powerful and have many useful features, they are also cumbersome and expensive. Many applications would benefit from using a small LIA circuit which can be included in the housing of the instrument, whether for simplification or portability. Some uses may present a dangerous environment for the use of an expensive laboratory grade instrument (Underhill *et al.*, 1991). Others may require operation where vibration, heat, or other considerations make the use of a commercial LIA less than optimum. The following circuitry is designed for these types of applications.

CIRCUIT DESCRIPTION

As shown in Figure 1, the preamplifier consists of a low offset, low-drift FET input LF411CN (Linear, 1987) operational amplifier which is connected to a PbSe detector (Infrared, 1990). An optical chopper operating at approximately 600 Hz is used to provide modulation. The gain of this amplifier is equal to the ratio of the feedback resistor (R6) to the input resistor (R5), which is connected to the inverting input terminal (negative). The feedback resistor is variable, therefore the gain of the circuit can be adjusted to the desired level. The feedback capacitor (C4) is sometimes called the "damping capacitance" and is mainly for stability, to protect against oscillation. This feedback circuit has a time constant of C4 x R6, and serves as a noise filter. However, it also sets the response speed, therefore it is necessary to select values that suit needed applications. When designing a preamplifier, it is necessary to consider impedance matching to the detector, low noise, and bandwidth. The PbSe has a load resistance of 0.5 M ohms and a dark resistance of 0.6 M ohms.

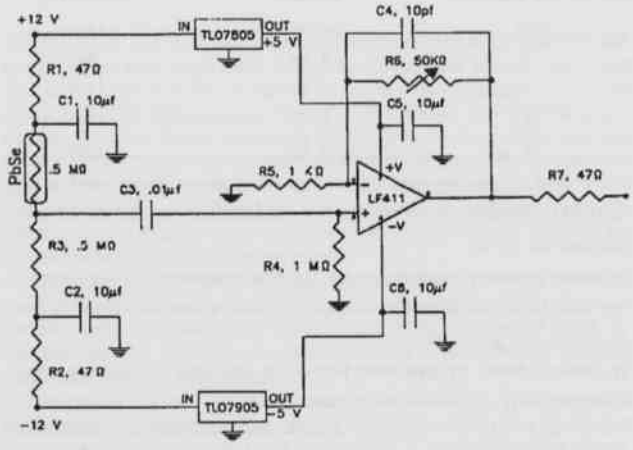

Figure 1. Pre-amplifier circuit, including PbSe detector.

When the load resistance and dark resistance are equal, the maximum signal can be obtained from the detector. A 0.5 M ohm resistor was selected as R3 to match the load impedance of the detector and achieve maximum output signal. The input impedance of the preamplifier was set to 1 M ohm (R4), which provides the path for AC signal from PbSe to ground. An AC-coupling capacitor (C3) was placed between the detector and the non-inverting input to block any DC signal and pass the 627 Hz ACsignal. To eliminate noise or ripple existing at the supply terminals at +/-12 volts, two low pass filters (R1, C1 and R2, C2) were employed. Since the 4066 synchronous detector switch, described later, operates at +/-5 volts, the supply voltage was regulated using two voltage regulators, TLO7805 (+5 volts, 100 mA) and TLO7905 (-5 volts, 100 mA). The +/-5 volts were used for all circuits except the PbSe detector, which used +/-12 volts. To buffer the output of the amplifier against oscillation, a 47 ohm resistor was placed in series at the output of the amplifier.

An important aspect of the modulation step is the generation of a reference signal that is the same frequency as the carrier wave (chopping frequency) and is phase-locked to it. Fig. 2 shows a reference signal circuit. The near IR radiation emitted at a wavelength of 940 nm from the infrared emitting diode (IRED) is chopped by the mechanical chopper at the same frequency as, and with a fixed phase relationship to, the analytical signal. A 330 ohm resistor (R8) is placed in series with the IRED to limit excess current. The IR phototransistor detects the 940 nm radiation through the opening of the chopper. This radiation causes the transistor to generate current. This current causes a voltage drop across the 1 K ohm resistor (R9). This voltage drop will be the voltage at the non-inverting

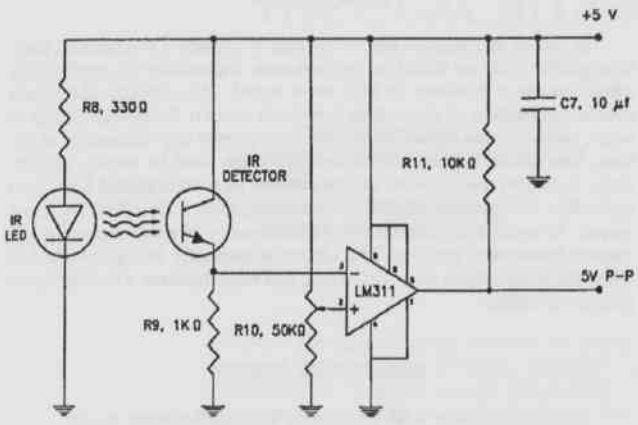

Figure 2. Optical chopper reference circuit.

input of the LM311N voltage comparator. The inverting input of the comparator is connected to a variable resistor (R10) which was selected to be 50 K ohms. This resistor was chosen on the basis of availability and because it does not draw appreciable current, which would effect the stability of the system. The value of this resistor was adjusted so it would have a voltage drop equal to half of the voltage across R9 to assure complete switching. The current through R9 introduces a small voltage to the inverting input that forces the comparator's output to go to a high voltage level. The output frequency will be exactly the same as the chopper's frequency. A 10 µf capacitor (C7) at the positive supply terminal eliminates any noise and/or ripple.

Figure 3 shows the main section of the synchronous demodulator which uses a CD4066 quad analog switch low offset, low drift JFET

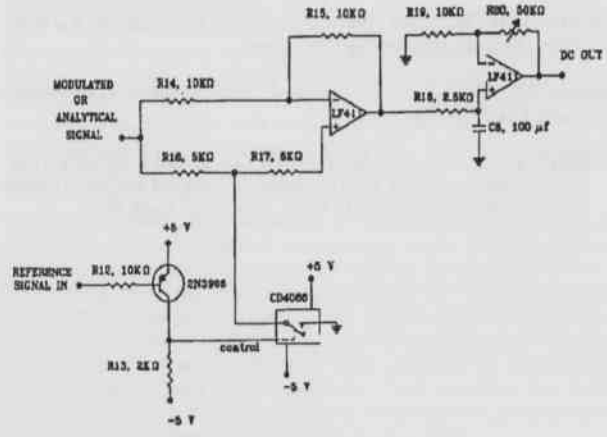

Figure 3. Synchronous detector circuit.

input operational amplifier (LF411), and a PNP transistor (2N3906). Since the analog switch operates in the range of +/-5 supply voltage, the reference signal needs to be translated. It should swing in the same range as the supply voltage. When the input signal at the base of the transistor is zero, the emitter voltage is more positive than the base voltage. This causes the output of the transistor at the collector to reach the maximum positive supply voltage. When base voltage from the reference reaches +5 volts it causes the output voltage of the transistor to reach its maximum negative supply voltage. The output of the transistor is being fed to the control pin of the analog switch. This switch will be turned on and off at the rate of the reference frequency. The output of the switch was connected to the input of the amplifier as shown. When the switch is open, the analytical signal passes through the (R15, R16) 10 K ohm resistors with a gain of -1. When the switch is closed, the analytical signal reaches the output of LF411 op-amp through the (R14, R15) 5K ohm and (R15,R16) 10K ohm resistors path with a total gain of +1. Therefore, the output has a gain of either +1 or -1, depending on switch state. The analytical signal will be recovered or demodulated as it comes out of the LF411 which acts as a synchronous rectifier or demodulator. Depending on the phase relation between the analytical signal and reference signal, the modulated signal can be either totally recovered or discriminated. Fig. 4 shows these relations. When the signal and the reference are in phase (0 degrees or 180 degrees), a strong DC term (positive for 0 degrees, negative for 180 degrees) is produced, which is proportional to the strength of the input signal. But when the reference and signal are out of phase (90 or 270 degrees), a zero DC term is produced completely rejecting the input signal. The recovered output goes through a filter (R17, C8) with a time constant of 250 ms for removing the AC components. The second LF411 was used for further amplification, if necessary, by using R18 and R19.

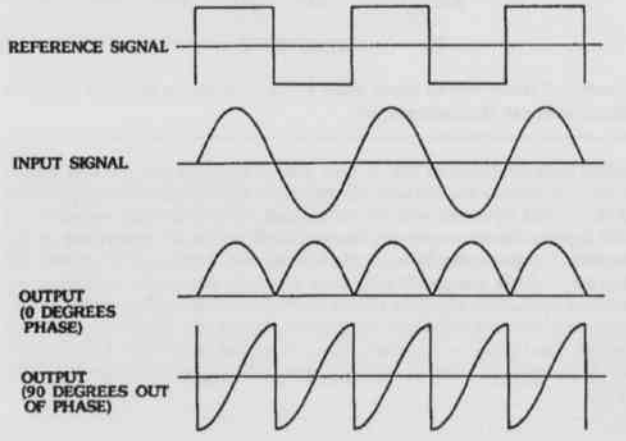

Figure 4. Synchronous detector input/output phase relationships.

APPLICATIONS

The circuit was initially tested using a signal generator and oscilloscope to monitor the signals present in/at each stage. This allowed confirmation of proper operation. Following testing, the circuit was placed into operation as the signal processor for a Flame Infrared Emission (FIRE) gas chromatography detector (Hudson and Busch, 1987; 1988) (Hudson *et al.*, 1990). Output of the synchronous detector was routed to a strip chart recorder. An output tracing is shown in Fig. 5. This tracing was obtained by injecting 4 ul of a mixture containing equal volumes of pentane, hexane, heptane, and cyclohexane into the GC. The column temperature was set to the boiling point of pentane, 69 °C, in order to assure complete separation. The separated compounds were combusted in a hydrogen/air flame to give the products carbon dioxide and water vapor. The emission resulting from each compound was detected by a PbSe (lead selenide) detector with an appropriate bandpass filter (4.3 µm for carbon dioxide). Signals were then sent to the circuit board for processing and recorded on a chart recorder. The FIRE trials indicate that the circuit is able to operate in place of a commercial, laboratory LIA for the processing of signals of moderate to high intensity. Signals recorded with this circuit were comparable to those obtained with an Ithaco 3961A LIA.

The circuit was also used as the signal processor in an IR radiometer for monitoring the IR emissions from rocket motor plumes. The circuit output was fed to an A/D board, located about 100 feet from the instrument. Again, the circuit performed as expected for an LIA, giving experi-

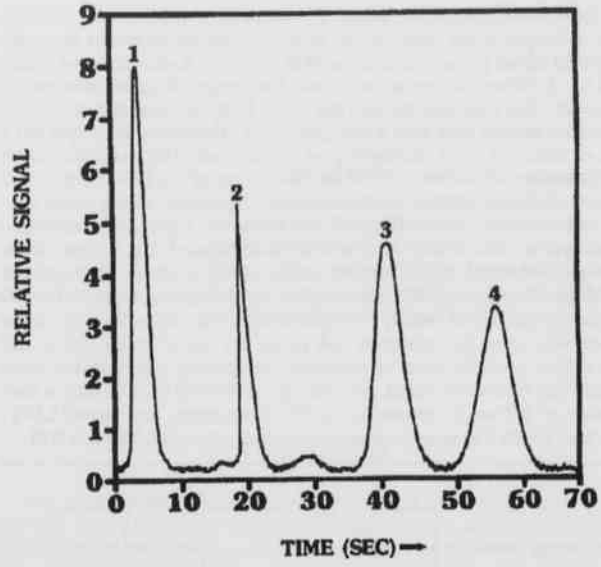

Figure 5. Circuit output when used as LIA for flame infrared emission detection in gas chromatography.

mental data as shown in Fig. 6. One area of concern was the long length of cable necessary for operator safety in this application. The output stage of the circuit operated with no oscillation, giving a clean signal at the A/D inputs. Another concern was the high ambient temperature of the test site. Temperatures in the bunker during the rocket test were near 100 degrees F. This temperature caused a barely noticeable difference in baseline level, with no other effects apparent. Additionally, high intensity noise and induced vibration are present during the test firing of rocket motors. These had no apparent effect on circuit operation. This application is reported in detail in another paper in this Journal (Underhill *et al.*, 1991).

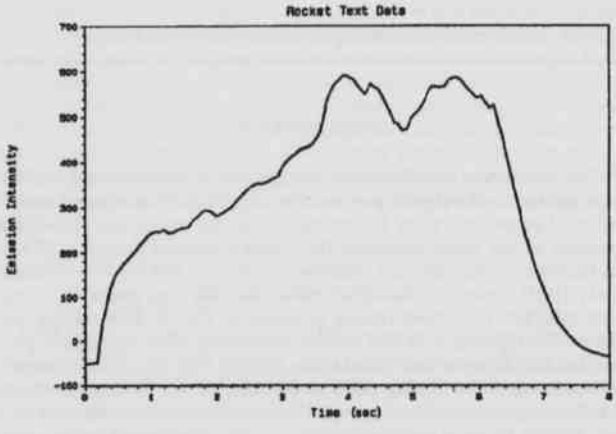

Figure 6. Circuit output when used as signal processor in IR radiometer for rocket plume monitoring.

CONCLUSION

The circuit as designed allows the user to replace a commercial lock-in-amplifier with no signal or performance degradation in applications which present a moderate to high level signal. Theoretically, the circuit should be capable of extracting low level signals from high levels of noise, however, this capability has not been proven experimentally at this time. The circuit has several advantages when used in certain applications. It is very economical in comparison to a commercial LIA. It is applicable in a process control environment, with little effect on signal output. Its small size makes it easy to incorporate as a signal processor in various instrument systems. The circuit is currently being modified to allow electronic phase shift, DC offset, and other features which will give greater versatility.

ACKNOWLEDGMENT

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PAST AND PRESENT DISTRIBUTION OF THE RED-COCKADED WOODPECKER *PICOIDES BOREALIS* AND ITS HABITAT IN THE OUACHITA MOUNTAINS, ARKANSAS

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ABSTRACT

Within the past 15 years, at least 41 and probably more active cavity tree clusters (or colonies) of Red-cockaded Woodpeckers *(Picoides borealis)* have existed in remnant, mature shortleaf pine *(Pinus echinata)* woodlands in the Ouachita Mountains of Arkansas. These clusters were located on both private timberlands and in the Ouachita National Forest. Fewer than half of this number were still active in early 1991, and none remained on private timberlands. The species is presently restricted to the xeric, western margins of the Ouachitas in Scott and Polk counties within the confines of the Ouachita National Forest where it receives protection of the Endangered Species Act. The decline of *P. borealis* in the Ouachitas resulted from intense logging of old growth pine forests during the timber boom period, ca. 1910-1950, and from the suppression of natural fires, which subsequently allowed hardwoods to invade former pine woodlands.

INTRODUCTION

The Red-cockaded Woodpecker *(Picoides borealis)* is an endemic species of mature pine forests in the southeastern United States (Jackson, 1971; USFWS, 1985). Adult pairs, which typically remain in the same territories throughout the year, are called clans or groups. The cluster of cavity trees used by the group has been termed a colony or colony site (Ligon, 1970; USFWS, 1985), but some authors prefer the term cluster because colony has a different and well-established meaning in ornithological literature (Walters *et al.*, 1988).

P. borealis was listed as an endangered species in 1970 (35 Federal Register 16047) due to a significant rangewide decline in numbers which resulted from decreased in quality and quantity of mature pine woodlands (Jackson, 1971; Lennartz *et al.*, 1983). A remnant population of Red-cockaded Woodpeckers still occurs on public lands in the western Ouachita Mountains of Arkansas and Oklahoma where habitat is managed to favor the species (USFWS, 1985; ODWC, 1991).

The question of the occurrence of this species, and the nature of its essential open pine woodland habitat, is potentially controversial because of a larger controversy about management of the Ouachita National Forest. This controversy involves advocates of clearcutting or even-age forest management and those who favor single-tree-selection or uneven-age forest management (Griffee, 1989; Arkansas Democrat, 1989). A basic element of this controversy concerns historical questions about vegetation composition and condition of forest stands in the Ouachitas and how these stands should be managed today. These questions have a direct bearing on present and future techniques of habitat management for the Red-cockaded Woodpecker (ONF, 1990; Anon., 1989).

STUDY AREA

The Ouachita Mountains (and the Ozark Plateaus to the north) comprise the Interior Highlands, which are the only extensive mountainous topography at the Arkansas latitude between the Appalachian Mountains to the east and the Rocky Mountains to the west (Fenneman, 1938; Foti, 1974; James and Neal, 1986). The Ouachitas are approximately 97 km (60 miles) in width and approximately 400 km (250 miles) in length, extending from Little Rock, Arkansas, westward to Atoka, Oklahoma (Fenneman, 1938). The total extent of the Ouachitas in Arkansas and Oklahoma is estimated at about 2.9 million ha (11,000 square miles) (Smith, 1986b) of which 648,000 ha (1.6 million acres) is included within the boundaries of the Ouachita National Forest.

The climax vegetation of the Interior Highlands is the Oak-Hickory Forest. On some sites within this forest, shortleaf pine is codominant with oak-hickory. Pure pine stands occur on sites unfavorable for growth of hardwoods as a result of a variety of factors (Mattoon, 1915; Little and Olmstead, 1931; Turner, 1935; Braun, 1967). The presence of pine in the Oak-Hickory Forest represents a subclimax maintained by fires (Odum, 1959) which have long been a feature of the Ouachitas (Little and Olmstead, 1931; Deaderick, 1938; Albert, 1981; Foti and Glenn, 1991).

The mountain-forming processes in the Ouachitas produced a series of directional folds evident as east-west ridges which cross the region. These ridges produce a variety of microclimates on the north-facing and south-facing slopes. The more protected north slopes have a climate most conducive to hardwoods. The south slopes are exposed to summer sun and hot, dry summer winds that produce desiccating conditions unfavorable to shortleaf pine or mixed forest types (Mattoon, 1915; Foti, 1974; Braun, 1967). In the Ouachitas, these conditions fostered what has been called the greatest shortleaf pine forest in the world (Smith, 1986a,b) and provided habitat suitable for Red-cockaded Woodpeckers and other species adapted to the fire subclimax.

METHODS

During 1989 and 1990 we surveyed all known Red-cockaded Woodpecker cavity tree clusters on the Poteau, Cold Springs, Mena, and Fourche Ranger Districts of the Ouachita National Forest in western Arkansas. We also checked inactive clusters further east in the Ouachita National Forest. Area searches were undertaken to discover new cavity trees as well as new woodpecker groups. A determination was made about whether or not cavity trees within each cluster were active or inactive (Jackson, 1977).

In spring 1990, prior to the Red-cockaded Woodpecker breeding season, a cooperative effort involving personnel from the Ouachita National Forest, University of Arkansas (including the Arkansas Cooperative Fish and Wildlife Research Unit and personnel from the Department of Zoology), Arkansas Natural Heritage Commission, Arkansas Audubon Society, Nature Conservancy, Arkansas Game & Fish Commission, U.S. Fish and Wildlife Service, and Forest Service volunteers surveyed all known active cavity tree clusters. All known Red-cockaded Woodpeckers in the forest were subsequently trapped and banded.

Literature searches (Jackson, 1978; James, *et al.*, 1981; James and Neal, 1986, 1989; unpub. data from Ouachita National Forest ranger districts) provided data about woodpecker distribution within the Arkansas Ouachitas. We queried the Arkansas Natural Heritage Commission's Inventory Research files of the Arkansas Ouachitas. Bird records maintained on file cards by the Arkansas Audubon Society provided data about Red-cockaded Woodpecker sightings. We conducted telephone interviews with personnel from the Ouachita National Forest, Weyerhaeuser Company, and members of the Arkansas Audubon Society.

In order to understand historical habitat conditions potentially suitable for Red-cockaded Woodpeckers, we searched literature for specific details and references about occurrences of fires that would have produced open pine woodlands in the Ouachitas. Literature concerning commercial logging of the Ouachitas was consulted since extensive logging would indicate former abundance of pine habitat.

RESULTS

In Tables 1and 2 we present a listing of past and present distribution of the endangered Red-cockaded Woodpecker in the Ouachita Mountains of Arkansas. This updates several previous reports about this woodpecker's status in the Arkansas Ouachitas (James, *et al.*, 1981; Burnside, 1983; James and Neal, 1986, 1989). Regrettably, no information is available about this species in the Arkansas Ouachitas predating a few Arkansas Audubon Society file reports in the 1960s. Private timber company records which might better document earlier occurrences in the eastern Ouachitas probably no longer exist (Tony Melchiors, pers. comm.). The Ouachita National Forest has very few records of Red-cockaded Woodpeckers before the 1960s (John McLemore, pers. comm.). Hence the decrease of Red-cockaded Woodpecker numbers we document here reflects only part of the decline of the species in the Arkansas Ouachitas.

Table 1. Formerly active cavity tree clusters of Red-cockaded Woodpeckers in the Ouachita Mountains, Arkansas.

1. Saline Co. T2N R18W. Active 1981 (JHB).
2. Saline Co. T1N R18W. Active 1981 (JHB).
3. Perry Co.* T2N R21W S3 (C654). Active 1981 (JHB, TM).
4. Perry Co.* T3N R19W S28 (C1424). Active 1981 (JHB, TM).
5. Perry Co. T3N R20W S22. Active 1981 (JHB).
6. Montgomery Co. T1N R23W S30. Inactive 1981 (DS).
7. Montgomery Co. T1S R24W S18. Active ca. 1976 (JD).
8. Yell Co. T2N R22W S23 (C634). Inactive 1981 (JHB).
9. Yell Co. T2N R24W S24. Inactive 1981 (JHB).
10. Yell Co. T1N R23W S9. Inactive 1980 (DS).
11. Yell Co. T2N R23W S21 (C605). Inactive 1980 (DS).
12. Yell Co. T2N R23W S21/22 (C606)**. Inactive 1980 (DS).
13. Yell Co. T1S R21W S4 (C647). Inactive 1980 (DS).
14. Clark Co. T7S R22W. Inactive 1981 (JHB).
15. Polk Co. T1S R32W S20. Inactive 1981 (JHB).
16. Polk Co. T1S R30W S23. Inactive 1981 (JHB).
17. Scott Co. T1N R27W S13/14. Inactive 1976 (JD).
18. Scott Co. T1N R31W S14 (C821). Inactive Jan. 1989 (JM).
19. Scott Co. T1N R32W S1 (C1282 S38). Active 1988 (WM).
20. Scott Co. T2N R31W S21 (C1265 S12). Active 1981 (WM).
21. Scott Co. T2N R30W S20 (C1251 S12). Inactive 1990 (WM).
22. Scott Co. T2N R30W S27 (C 1260 S30/6). Active 1982 (WM).
23. Scott Co.* T2N R32W S24 (C1254). Inactive 1979 (WM).
24. Scott Co. T2N R32W S26 (C1261 S5). Active May 1979 (WM).
25. Scott Co. T2N R32W S26 (C1267 S5). Inactive 1979 (WM).
26. Scott Co. T2N R33W S24 (C1267 S14). Inactive 1979 (WM).
27. Scott Co. T2N R32W S30 (C1266 S14). Inactive 1979 (WM).
28. Scott Co. T2N R31W S20 (C1253 S7). Active May 1981 (WM).
29. Scott Co. T2N R31W S8 (C1243 S5). Inactive 1978 (WM).
30. Scott Co. T2N R31W S15 (C1244 S11). Active 1979 (WM).
31. Scott Co. T2N R31W S14 (C1244 S5). Inactive 1979 (WM).
32. Scott Co. T2N R30W S31 (C1274 S13). Inactive 1978 (WM).
33. Scott Co. T2N R30W S29 (C1261 S23). Active May 1980 (WM).
34. Scott Co. T2N R30W S20 (C1261 S1). Inactive 1978 (WM).
35. Scott Co. T2N R30W S35 (C1273 S10). Inactive 1978 (WM).
36. Scott Co. T2N R29W S22 (C1256 S5). Inactive 1979 (WM).
37. Scott Co. T1N R28W S5 (C1293 S20). Active May 1979 (WM).
38. Scott Co. T1N R25W S6 (C1294 S10). Active 1979 (WM).
39. Scott Co. T2N R29W S29 (C1257 S21). Active 1979 (WM).
40. Scott Co. T1N R30W S13 (C1305 S11). Inactive 1980 (WM).
41. Scott Co. T3N R28W S33 (C294). Inactive 1979 (WM).

Location includes county, legal description and Forest Service compartment (C) and stand (S) numbers where appropriate (or where available) followed by last known date when the site was active or known to have become inactive. JHB=James, Hart and Burnside 1981; WM=Warren Montague; DS=Dave Saugey; JM=Jim Mawk; TM=Tony Melchiors; JB=Joe Dabney. *=cavity tree cluster on private land **=May have been two clusters rather than one.

Table 2. Locations of active Red-cockaded Woodpecker cavity tree clusters as of March 1991 in the Ouachita Mountains, Arkansas.

1. Scott Co. T2N R29W S20. (C1257 S28)*
2. Scott Co. T2N R29W S20. (C1257 S20)*
3. Scott Co. T2N R29W S20. (C1259 S14)*
4. Scott Co. T2N R30W S28. (C1261 S7)*,*****
5. Scott Co. T2N R30W S27. (C1261 S8)*
6. Scott Co. T2N R31W S20. (C1253 S5)*
7. Scott Co. T2N R31W S10. (C1244 S12)*
8. Scott Co. T2N R31W S22. (C1252 S25)*
9. Scott Co. T2N R31W S36. (C1274 S9)*
10. Scott Co. T2N R28W S10. (C323 S23)*
11. Scott Co. T2N R28W S10. (C323 S13)*
12. Scott Co. T2N R28W S8. (C326 S14)*
13. Scott Co. T2N R29W S29. (C1257 S22)**
14. Scott Co. T2N R28W S3 (C323 S14)*** (discovered 24 Jan. 1991)
15. Scott Co. T2N R30W S29 (C1262 S12)****
16. Polk Co. T1S R29W S19 (C862 S25)*** (discovered December 1990)

All active clusters were located within the boundaries of the Ouachita National Forest. Location includes legal description, plus Forest Service compartment (C) and stand (S) designations. *=clan nested in 1990; **=clan did not nest in 1990; ***=new clan December 1990; ****=single female captured and moved (16 March 1990), cluster now inactive; *****=cluster apparently became inactive after 14 November 1990.

Table 1 lists 41 inactive cavity tree clusters in the Arkansas Ouachitas which are either: (1) inactive with no evidence of former Red-cockaded Woodpecker activity; or (2) inactive at present, but having at least some evidence of former Red-cockaded Woodpecker activity. Last known date of activity is provided. Some sites, especially those in the eastern Ouachitas, were active for a few years longer, but no documentation exists to this effect. Activity in Red-cockaded Woodpecker cavity tree clusters in the western Ouachitas has been well-documented since the late 1970s.

Surveys of Red-cockaded Woodpecker cavity tree clusters from June 1990 to March 1991 in the Ouachita National Forest of western Arkansas documented 16 clusters with 15 of the associated groups having a minimum of a male-female pair (Table 2). Of these 16 clusters, 12 had nesting pairs in the 1990 season. An unpaired female in one cluster was captured and moved into another cluster where there were two males but no female. While this caused the loss of one active site, it resulted in egg laying in another site when the female paired with one of two bachelor males. By March 1991, two new groups had been discovered and one formerly active cluster had apparently become inactive. All active clusters of cavity trees are in Scott or Polk counties, Arkansas.

Our literature searches showed that a number of writers in the past have described habitat in the Ouachita Mountains that would now be recognized as fire subclimax woodlands suitable for Red-cockaded Woodpeckers. They reported extensive pine stands (Nuttall, 1821; Mattoon, 1915; Bruner, 1931; Deaderick, 1938; Smith, 1986 a,b) and frequently referred to natural fires. We also found eyewitness references to pure pine stands (Mattoon, 1915; Bruner, 1931; Turner, 1935) which are clear indications that this classical Red-cockaded Woodpecker habitat existed in past years in the Ouachitas.

DISCUSSION

The original decline of the Red-cockaded Woodpecker probably resulted from logging booms that virtually eliminated virgin pine stands in the Southeast by the 1930s (Smith 1986 a,b; Jackson, 1988). Suppression of fire, which naturally maintained pine dominance in certain stands, permitted widespread development of hardwood midstories and eventual replacement of pine stands by hardwoods (Mattoon, 1915; Bruner, 1931; Liming, 1946). Modern timber management practices, which favor short rotation periods, have further reduced the once extensive mature pine woodland (Mattoon, 1915; James and Neal 1986, 1989; Jackson, 1988).

Fire is a key natural feature in the evolution of the Red-cockaded Woodpecker and its habitat (Jackson, 1971, 1988). Fires in the Southeast are often set by lightning (Komarek, 1973). Fires that sweep through these forests naturally exclude development of hardwood understories and midstories, thereby maintaining the open stands of fire-resistant large pines

(Odum, 1959) required by this woodpecker (USFWS, 1985; Jackson, 1988). A notable feature of this fire subclimax forest is a Pleistocene relict grassland of characteristic grasses, herbs, and legumes present in regularly burned pine forests throughout the Southeast (Komarek, 1968). The term savanna has been applied to these open canopy forests with graminoid-dominated understories maintained in a subclimax condition by fire (Penfound and Watkins, 1937; Penfound, 1962; Christensen, 1988), but the term woodland is more appropriate in the forest-like situations of the Ouachitas (D. James, pers. comm.). The adaptation of the Red-cockaded Woodpecker to this fire subclimax regime makes it a unique indicator of the system (Jackson, 1987).

Studies of the development of forests in the western Ouachitas have established that pine became a notable feature of the Oak-Hickory Forest approximately 1600 years ago (Albert, 1981; Albert and Wyckoff, 1984). Charcoal deposits in the western Ouachitas provide evidence of periodic widespread fires which favored the spread of both oak and pine woodlands. In the era before modern fire suppression, researchers estimated that from one-third to three-fourths of the Oklahoma Ouachitas were burned annually (Little and Olmstead, 1931). There is good documentation of the frequent occurrence of fire on a study site in Hot Springs National Park, ca. 1800 (Foti and Glenn, 1991). Fire seems to have occurred there at an interval of about 27 years per hectare; the mean fire-return interval from 1788-1817 was 7.25 years, based upon fire scars on an old shortleaf pine tree. Foti and Glenn (1991) conclude that shortleaf pine was ubiquitous in the pre-settlement forests of the Ouachitas, with most pines occurring on south aspects and intermediate slopes, but also with a surprising number on northwest slopes. Hardwoods, primarily oaks, were also a major component of most sites.

Fire may have created the pine stands seen by early travelers like Thomas Nuttall (1821) who saw "pine hills," "lofty pine hills," and "hills in this cove, which abound with pine" in the Kiamichi region of southeastern Oklahoma. Other natural agents were also at work in shaping the forest community. Mattoon (1915) described the destructive path of a tornado near Womble in Montgomery County, Arkansas, that flattened an area 14 miles long by one-half mile wide; it eventually regrew as an even-age pine stand. Turner (1935) also described pure pine stands in Howard County, Arkansas, that resulted from wind damage. Bruner (1931) described basically pure stands of pine, with trees 10-15 inches in diameter in even-aged stands. Deaderick (1938), a student of the Ouachita's avifauna, wrote that almost the entire Hot Springs area was covered with second growth shortleaf pine and that 75% of Garland County was once pine forest. He also noted that fires occurred often enough "to sweep the ground cover of the pine woods clean."

In a treatise about shortleaf pine based upon data drawn extensively from the Arkansas Ouachitas, Mattoon (1915:4) notes that,

> Shortleaf is very well adapted for growth in pure stands, and it occurs extensively in this form of forest. The stands are usually not continuous over large areas, but are separated by mixed stands of pines and hardwoods. Stands of pure shortleaf pine once covered a much larger area than at present. It should be doubtful whether shortleaf is now found in pure type on more than from 20 to 40 percent of its former range.

Based upon logging records, Smith (1986b) estimates that approximately 1.3 million ha (5000 square miles) of the 2.9 million ha (11,000 square miles) of the Ouachita Mountains were probably cut over during the logging boom. Photographs of log yards and log trains published by Smith (1986a) show massive pines with the darkened heartwood typical of mature pines infected with the heartwood decaying fungus *Phellinus pini*. Such trees are frequently selected by Red-cockaded Woodpeckers for cavity construction (Conner and Locke, 1982). Smith (1986b) states that photographs from the period 1900 to 1948 show pine logs ranging from 12 to 28 inches in diameter. A report written for the Weyerhaeuser Company concerning the history of Ouachita logging operations it acquired from the Dierks Company indicates that trees less than 30 cm (12 inches) in diameter at breast height were not cut during logging of the virgin forest (Anon., ca. 1970). Mattoon (1915) notes that about 11% of virgin shortleaf pine logs were infected with heart rot, and that these trees ranged from 60 to 180 years in age, with some being over 200. These old trees would have been suitable for Red-cockaded Woodpeckers and some of the smaller trees that survived the first cut eventually provided replacement cavity trees for the remnant population of woodpeckers.

We infer that when natural disasters occurred on southern aspects, it was likely that the new openings in the forest were colonized by shortleaf pine, probably as even-age stands as discussed by Turner (1935). The fire adaptation of shortleaf pine (Mattoon, 1915) meant that fire-created openings were reestablished as pure stands of pine. Therefore, while the total amount of suitable habitat for a once more widespread and numerous population of Red-cockaded Woodpeckers isn't known, stands of pure pine or pine woodlands existed historically and within recent times. Wood's (1977) documentation of 29 active Red-cockaded Woodpecker clans and cavity tree clusters on 3,795 ha of virgin pine-oak forest in the McCurtain County Wilderness Area suggests how dense the population of woodpeckers may have been prior to the logging boom and the suppression of fire in the Ouachitas.

When the Arkansas (later renamed Ouachita) National Forest was established in 1907, both public and private lands were included within its boundaries. Much of the public land included the core areas of the Ouachitas, especially mountain ridges, narrow canyons, and some wide valleys with difficult access (Smith, 1986a). We hypothesize that the inaccessibility of some of these areas inhibited timber removal during the original logging boom. Remaining trees were most likely older suppressed trees with small diameters that were common in this forest (Mattoon, 1915). Many of these suppressed trees were bypassed in the cutting. Removal of the dominant trees released these suppressed trees for renewed growth. As these once suppressed trees grew larger, they became available as Red-cockaded Woodpecker cavity trees.

The eastern region of the Ouachitas is poorly represented by records of Red-cockaded Woodpeckers. Historically, however, the species was widespread to the west, south, and southeast of the Arkansas Ouachitas (Hooper *et al.*, 1980; James and Neal, 1986). The large-scale railroad map presented by Smith (1986a) illustrates that many areas in the eastern and central Ouachitas were accessed by an extensive web of railroad lines which carried pine logs to mills. Habitat of the woodpecker was rapidly cut. The situation in the western Ouachitas may have been somewhat different. Active clusters remain only in that section of the Ouachitas called the Fourche Mountains in Arkansas and the Kiamichi Mountains in Oklahoma (Fenneman, 1938). The Fourche-Kiamichi comprises the region's highest and most massive mountains and includes those sections of McCurtain County, Oklahoma, and Scott and Polk counties, Arkansas, where active clusters remain. We hypothesize that this rugged terrain may have hindered logging such that isolated pockets of habitat and scattered suppressed trees survived, thus providing habitat for a remnant population of woodpeckers. The preservation of the McCurtain County Wilderness Area in 1917 (Masters *et al.*, 1989) and its associated virgin pine and pine-oak forest, explains survival of the species there.

Prescribed fires in the Ouachita National Forest are used routinely for Red-cockaded Woodpecker habitat management. Fire suppression in the McCurtain County Wilderness area led to development of dense hardwood midstories and probable loss of half of the Red-cockaded Woodpecker groups (Wood, 1977; Masters *et al.*, 1989). Prescribed fire is being incorporated into future management plans (Oklahoma DWC, 1991). Retention of the current population of Red-cockaded Woodpeckers in the Ouachitas will require continued special attention to habitat management in this 3-county area which straddles the Arkansas-Oklahoma border. Forest management which replicates the open pine woodland condition of the past will be the most effective way of promoting recovery expansion of the Red-cockaded Woodpecker.

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REPRODUCTIVE PERFORMANCE OF FEMALE WHITE-TAILED DEER ON HOLLA BEND NATIONAL WILDLIFE REFUGE

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ABSTRACT

Aspects of the reproductive biology of female white-tailed deer *(Odocoileus virginianus)* on Holla Bend National Wildlife Refuge were investigated by examining the reproductive tracts of 121 deer harvested during the 1985-90 archery seasons. The presence of corpora albicantia in yearlings suggested that 27% of female fawns conceived, producing a mean of 1.0 ova/breeding fawn. Pregnancy rates among yearlings and adults averaged 94% and 97%, respectively. Ovulation rates averaged 1.4 and 2.0 ova/female among yearlings and adults. Some females were ovulating in early-October, but the earliest conceptions occurred during the last week of October. The peak breeding period for yearlings and adults was during mid- and late-November. No fawns ovulated prior to December 1. The implantation rate averaged 91% among yearlings and adults.

INTRODUCTION

The white-tailed deer *(Odocoileus virginianus)* is the most abundant big game animal in Arkansas. Successful deer management programs depend in part on a thorough understanding of the species' population dynamics, including natality, mortality, immigration, and emigration. Of these, natality is most easily estimated, and thus may be the most useful to deer managers and biologists.

To date, only one published study has addressed natality in Arkansas' deer populations (Wilson, 1971). The purpose of this study was to compare reproductive performance of females living on Holla Bend, with that of deer state-wide as reported by Wilson (1971). The objectives of the research were to: (1) delineate the beginning and peak period of reproduction, (2) estimate age-specific ovulation rates, (3) estimate the percentage of female fawns breeding, and (4) estimate implantation rates (percentage of ova fertilized and implanted).

STUDY AREA

Holla Bend is a 1,652 ha Refuge located on a former oxbow of the Arkansas River, 15 km SE of Russellville. The Refuge is managed primarily as a wintering area for waterfowl but supports a large deer population estimated at 300-350 animals.

Plant communities found on the Refuge consist mainly of agricultural fields (corn, soybeans, milo, and millet), old fields, and bottomland hardwood forests dominated by cottonwoods *(Populus deltoides)*, pin oaks *(Quercus palustris)*, and pecans *(Carya illinoiensis)*.

The nutritional plane of resident deer is quite high, due in part to a diet high in corn and soybeans (Nelson *et al.*, 1988). Holla Bend provides a particularly suitable location for studying reproduction of deer because of the: (1) large resident deer population, (2) high quality of habitat, (3) controlled access to the area (entrance and exit is through a single gate), (4) availability of deer carcasses over a long (75-day) period during the breeding season, and (5) requirement that hungers bring harvested deer to a central check-station prior to field dressing the carcass.

MATERIALS AND METHODS

Complete reproductive tracts (ovaries, oviducts, and uteri) were collected from 121 female deer harvested by hunters on the refuge during the 1985-90 archery (Oct. 1 through Dec. 15) deer seasons. The age (estimated by tooth replacement and wear), weight, and condition (based on fat reserves and abomasal parasite counts) were also recorded for each animal (Severinghaus, 1949; Riney, 1955; Eve and Kellogg, 1977). Each tract was labelled and preserved in 10% formalin for subsequent processing. Only those tracts with both ovaries and the uterus intact were preserved.

Temporal analysis of the breeding season was conducted by grouping females harvested during each 2-week period of the archery season. Ovaries were gross-sectioned and analyzed following the method of Cheatum (1949), as modified by Teer *et al.* (1965). Corpora lutea (CL) were considered corpora lutea of pregnancy (CLP) if they were at least 4 mm in diameter. Smaller CLwere considered corpora lutea of estrus (CLE), and were not used to delineate the breeding season in this study (Mansell, 1971).

Uteri were flushed with water and examined for incidence and number of embryos or early-embryonic tissues. The age of each embryo was estimated based on crown-rump length (Armstrong, 1950). Back-dating each embryo from the date of harvest provided estimates of conception dates.

Ovulation rates (number of ova per female) and pregnancy rates (percentage of females pregnant) for each previous year were estimated from counts of corpora albicantia (CA) (Teer *et al.*, 1965). Age-specific ovulation and pregnancy rates were estimated by pooling data from individuals in the fawn (0.5 years old), yearling (1.5 years old), and adult (>1.5 years old) age classes.

RESULTS AND DISCUSSION

TIMING OF OVULATION

The first ovulation of the breeding season frequently does not lead to conception in white-tailed deer (Harder and Moorhead, 1980). Harder (1980) noted that this initial ovulation was not accompanied by estrus, perhaps due to an incomplete hormonal regime. Usually the resulting CLE regresses quickly, and a second ovulation occurs within 2 weeks, usually resulting in fertilization and the development of a larger CLP.

CLE's were evident in some yearling and adult females on Holla Bend in early-October. However, CLP were rarely observed in females harvested prior to the last week of October; two yearlings killed in mid-October did have CLP present. Both of these individuals were particularly fat, and had not produced fawns during the summer. Perhaps relieved of the energetic costs of pregnancy and lactation, they reached a breeding condition earlier than others.

During the first half of November, 75% of yearlings and 55% of adults had CLP. By the end of November, 95% of both classes had CLP present, suggesting that the peak period of breeding occurred during mid- and late-November. This was also the period when peak numbers of spermatozoa were found in the reproductive tracts of adult male deer on Holla Bend (Nelson and Johnson, 1990). Of 20 female fawns examined, none were found to have CLP before December 1. However, among fawns harvested during December 1-15, 16% had developed these structures. Prior studies have shown that fawns frequently breed later than older deer (Roseberry and Klimstra, 1970; Wilson, 1971). On Holla Bend, fawns apparently breed in December, 2-4 weeks after older deer.

AGE-SPECIFIC OVULATION RATES

Mean ovulation rates for fawns, yearlings, and adults were estimated by counting CA in yearlings, 2.5-year olds, and older deer, respectively. Cheatum (1949) estimated that CA persist for 8-12 months following pregnancy, and thus were a reliable indicator of ovulation rates the previous year. Subsequent studies suggested that approximately 15% of CA persist 2-3 years (Golley, 1957; Mansell, 1971). Therefore, CA counts may over-estimate true ovulation rates. In our sample, yearlings averaged 1.4 CA/doe and adults averaged 2.0 CA/doe. Assuming a 15% carryover of CA from previous years, these data suggest that "true" ovulation rates approximate 1.2 and 1.7 ova/doe for yearlings and adults, respectively.

Pregnancy rates could not be estimated directly from CLP in harvested females, as some females would not have conceived when sampling ended on December 15. However, the incidence of CA provides a good estimate of pregnancy rates from each previous year. Based on the percentage of females with visible CA, pregnancy rates were estimated to be 27%, 94%, and 97% for fawns, yearlings, and adults, respectively.

Ovulation rates of white-tailed deer populations in the eastern United States have been found to vary widely. Age and nutrition are thought to be the major influences on reproductive performance (Harder, 1980). Ovulation rates typically increase in each age-class through the first 3 years of life, after which age has little influence.

A large body of research suggests that nutrition also affects reproductive performance, particularly ovulation rates. Poor nutrition, whether due to drought, severe winters, poor habitat, overcrowding, or low soil fertility, generally leads to delayed maturity of female fawns, fewer fawns breeding, and lower ovulation rates among older females (Hesselton and Sauer, 1973; Harder, 1980).

Harder (1980) reported that ovulation rates for adults varied from 1.5 to 2.1 in 10 north central states. The percentage of pregnant fawns varied from 0 to 74%, presumably due to the quality and quantity of available food.

Wilson (1971) estimated a mean ovulation rate of 1.77 ova/doe using CA counts from a sample of 108 yearling and adult females collected across Arkansas. Note that this estimate was not reduced to account for carryover CA from prior breeding seasons.

He found no significant differences in ovulation rates among deer collected in north, central, and south Arkansas. However, deer from physiographic areas that differ significantly in soil fertility and habitat characteristics (e.g. Ouachita mountains and central Delta regions) were pooled for analysis. It seems likely that this pooling may have masked differences among deer in different physiographic regions. Wilson (1971) estimated pregnancy rates of 93% for yearlings and adults, and 41% for fawns.

The reproductive performance of deer on Holla Bend was generally similar to Wilson's (1971) state-wide estimates. Agricultural crops are available on Holla Bend throughout much of the year, and deer are generally in good condition. The advantage provided by these crops, however, may be offset by the high density of the population (approximately 20 deer/km^2). Consequently, females on the Refuge attained but did not greatly exceed, reproductive levels reported by Wilson (1971) in other regions of Arkansas. It should be noted, that the Arkansas deer population has increased significantly since 1971, and deer in many areas may not attain reproductive levels comparable to those reported by Wilson at that time. Another statewide study seems warranted.

Sixteen females carried visible embryos at the time of harvest. Comparing the number of embryos to the number of CLP provided an estimate of the loss of ova between ovulation and subsequent implantation. These data suggest an implantation rate of 91%. Information presented by Harder (1980) indicate that implantation rates typically exceed 87% in most deer populations.

Attempts are currently underway to refine deer management in Arkansas. These efforts include the development of population simulation models to help predict population size and explore the impacts of various harvest scenarios. A necessary prerequisite to the development of realistic models is good estimates of important population measurements, including natality. This study and the previous study by Wilson (1971) provide a basis for estimates of natality in Arkansas deer.

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AN ANALYSIS OF STOMACH CONTENTS OF THE OUACHITA MADTOM *(NOTURUS LACHNERI)* IN THREE STREAMS OF THE UPPER SALINE RIVER DRAINAGE, ARKANSAS

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ABSTRACT

A study was conducted to identify typical foods eaten by the Ouachita madtom *(Noturus lachneri)*, an endemic ictalurid of central Arkansas, and to compare these foods to the invertebrate community. Fish and invertebrate samples were collected in August and October, 1990, from a pool and adjacent riffle habitat in each of 3 streams in the upper Saline River drainage. Kick-net and electrofishing samples were collected at each site and the invertebrate organisms were identified to the lowest possible taxa. Stomachs from the *N. lachneri* specimens were removed and the contents were identified to order. Frequency of occurrence of each taxon was compared between stomach contents and kick-net samples. Similarities between kick-net samples and stomach contents indicate that *N. lachneri* specimens were not highly selective in food preference in the riffle and pool habitats of these Ouachita Mountain streams.

INTRODUCTION

The Ouachita madtom (*Noturus lachneri* Taylor) is an endemic ictalurid of the upper Saline and Ouachita rivers located in the Ouachita Mountains of central Arkansas (Robison and Buchanan, 1988). This species is not federally protected but has been considered threatened because of its small population size and habitat vulnerability (Robison and Harp, 1985). The possibility of habit degradation due to land management practices and road and bridge construction has increased the need for ecological studies of this species.

Robison and Harp (1985) reported that *N. lachneri* inhabits clear, high gradient streams, having a cobble, gravel, or fine substrate. Individuals are found in the quiet backwater areas of these streams.

Preliminary studies indicated that *N. lachneri* feeds mostly at night (Robison and Harp, 1985) as do several other members of the genus *Noturus* (Pfleiger, 1975). Nineteen specimens of *N. lachneri* were examined by Robison and Harp (1985) for food items. Insect larvae of the orders Ephemeroptera and Diptera were the most prevalent. The objective of the present study was to further characterize the foods eaten by *N. lachneri* and to compare these to the aquatic invertebrate community.

METHODS

Collections were made from 3 streams within the Saline River drainage. These streams included: (1) Cypress Creek near Paron Arkansas, (2) Alum Fork upstream of Lake Winona, and (3) Bread Creek, a tributary of Alum Fork. Six sample sites were selected. We chose one pool and an adjacent riffle habitat in each of the three streams. Each sample site was characterized with respect to physical parameters as described by Platts *et al.* (1987) and McCain *et al* (1990). Variables included widths, depths, and substrate composition (Table 1). Sample sites were selected with regard to density of *N. lachneri* collected in previous samples (Tatum, unpublished data). Benthic macroinvertebrates and *N. lachneri* specimens were collected on 8-13-90, 8-24-90, and 10-28-90. Fish were collected the day following invertebrate collections.

Table 1. Physical variables of three streams of the upper Saline River drainage, Saline County, Arkansas.

	Alum Fork		Bread Creek		Cypress Creek	
	Pool	Riffle	Pool	Riffle	Pool	Riffle
Average Depth (cm)	52	17	25	4	17	7
Average Width (m)	9	9	8	2	7	3

	Substrate Composition (%)		
	Boulder[1]	Cobble[2]	Gravel[3]
Alum Fork, riffle	30	50	20
Alum Fork, pool	25	50	25
Bread Creek, riffle	20	40	40
Bread Creek, pool	25	60	15
Cypress Creek, riffle	40	50	10
Cypress Creek, pool	30	60	10

[1] >20 cm
[2] >8 cm <20 cm
[3] <8 cm

Aquatic invertebrates were dislodged by systematically kicking the substrate in each site for five minutes. The dislodged organisms were collected in a 25 cm x 40 cm hand-held net (1 mm mesh) and preserved in 70% ethanol. In the laboratory, benthic organisms were identified to family using keys by Pennak (1978) and Merritt & Cummins (1984). Individuals were counted (Table 2) and stored in a reference collection (Arkansas Tech University). Betty Cochran (fisheries biologist, U.S.

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Forest Service, personal communication, 2-15-91) verified the identifications. Frequency of occurrence and relative frequency values were determined for each order.

Table 2. Numbers of aquatic invertebrates from kick-net samples from upper Saline River drainage, Saline County, Arkansas.

Taxa	Pools	Riffles	Summer	Fall	Total
Coleoptera	107	104	138	73	211
Trichoptera	3	5	2	6	8
Ephemeroptera	261	358	150	469	619
Plecoptera	5	11	7	9	16
Megaloptera	7	18	8	17	25
Odonata	63	34	45	52	97
Diptera	11	9	14	6	20
Isopoda	35	54	22	67	89
Decapoda	10	22	9	23	32
Sample Size	6	6	6	6	12

Noturus lachneri specimens were collected by electrofishing. The two-man crew collected as many *N. lachneri* as possible in one pass through each site. One to seven specimens from each sample site were preserved in 10% formalin. Abdominal cavities were injected with 10% formalin to halt further digestion and to preserve the contents. Fish were collected between 2300 and 0100 hrs and between 0400 and 0700 hrs during the summer sample. A higher proportion of fish collected in the morning had full stomachs, therefore subsequent sampling was in the morning (0400 to 0700).

Within the next four months, stomachs were removed from each specimen. The contents were identified to order, counted (Table 3), and retained in individual vials in 70% ethanol. Frequency of occurrence and relative frequency values were determined for each taxon. The macroinvertebrate reference collection from our kick-net sampling was used for comparison with the stomach contents as an aid in identification.

Table 3. Numbers of aquatic invertebrates from stomach contents of the Ouachita madtom *(Noturus lachneri)*, upper Saline River drainage, Saline County, Arkansas.

Taxa	Pools	Riffles	Summer	Fall	Total
Coleoptera	3	11	12	2	14
Trichoptera	-	1	-	-	1
Ephemeroptera	32	42	46	28	74
Plecoptera	35	15	-	50	50
Megaloptera	20	24	36	8	44
Odonata	-	1	0	1	1
Diptera	66	83	99	50	149
Isopoda	12	15	16	11	27
Decapoda	3	1	1	3	4
Zooplankton	28	78	69	37	106
Sample Size	26	25	23	28	51

Frequency of occurrence values from stomach contents and kick-net samples were compared to determine if differences existed between organisms consumed and the availability of those organisms. Frequency of occurrence values of stomach contents and kick-net samples were also used to determine if differences existed between habitats and seasons.

RESULTS AND DISCUSSION

Of the 51 *Noturus lachneri* specimens examined, 45 had food in their stomachs. A total of 12 kick-net samples was taken to characterize the benthic macroinvertebrate communities. Comparisons were made to determine if habitat or seasonal variations existed with regard to prey availability and food preference. Comparisons of frequency of occurrence values revealed little difference between pool and riffle habitats in the kick-net samples and the stomach contents (Fig. 1). There was little seasonal difference in the kick-net samples. Fall stomach contents showed a lower frequency of occurrence of coleopterans and megalopterans than in summer samples, and a higher frequency of occurrence of trichopterans, plecopterans, odonates, and decapods (Fig. 2). Variation in the seasonal use of these taxa may be due to increased size and mobility of coleopterans and megalopterans than in summer samples, and a higher frequency of occurrence of trichopterans, plecopterans, odonates, and decapods (Fig. 2). Variation in the seasonal use of these taxa may be due to increased size and mobility of coleopterans and megalopterans during their development (Figures 1 and 2).

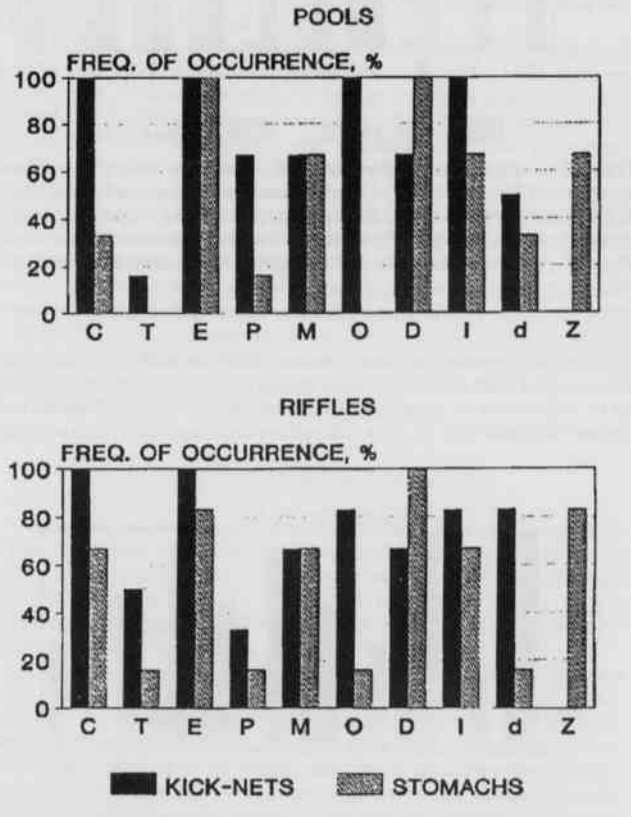

Figure 1. Comparisons of frequency of occurrence values of kick-net samples and *Noturus lachneri* stomach contents by habitat type from streams of the Saline River drainage, Saline County, Arkansas. Upper case letters on the X axis represent the first letter of the taxon (see Table 2), the lower case "d" represents decapods, and the upper case Z represents zooplankton.

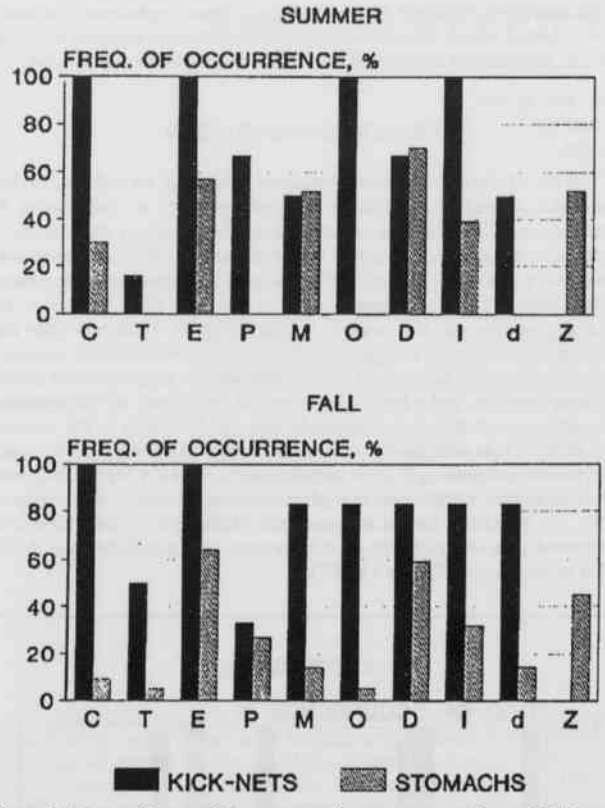

Figure 2. Comparisons of frequency of occurrence values of kick-net samples and *Noturus lachneri* stomach contents by seasons from streams of the Saline River drainage, Saline County, Arkansas. Upper case letters on the X axis represent the first letter of the taxon (see table 2), the lower case "d" represents decapods, and the upper case Z represents zooplankton.

Because we concluded that there was little seasonal or habitat variation, samples were combined for an overall comparison between frequency of occurrence of organisms from kick-net samples and those from stomach contents (Fig. 3). This comparison indicates that *N. lachneri* may be a largely opportunistic feeder. All organisms collected in the kick-net samples were found in at least one madtom stomach. Diptera, Ephemeroptera, Megaloptera, Isopoda, and zooplankton had the highest frequencies of occurrence in stomach contents. The kick-nets were not designed to capture zooplankton, though cladocerans and copepods appeared frequently in the stomach contents. The decapods consumed were small (<10 mm). Frequency of occurrence values of decapods in the kick-net samples were higher than in the stomach contents. However, most collected in the kick-nets were too large to be a prey source for *N. lachneri*. No organic detritus was found in any of the stomach contents. Though it has been indicated that some madtoms are known to be piscivorous, such as *Noturus exilis* (Madyen and Burr, 1981), none of the stomachs of *N. lachneri* examined in this study contained fish (Fig. 3).

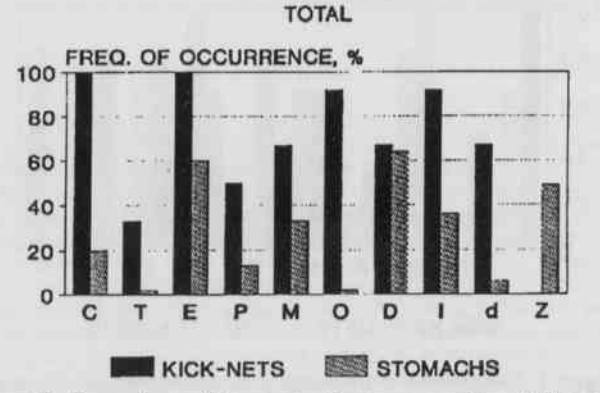

Figure 3. Comparisons of frequency of occurrence values of kick-net samples and *Noturus lachneri* stomach contents from streams of the Saline River drainage, Saline County, Arkansas. Upper case letters on the X axis represent the first letter of the taxon (see table 2), the lower case "d" represents decapods, and the upper case Z represents zooplankton.

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OBSERVATIONS ON THE NATURAL HISTORY OF THE MEDITERRANEAN GECKO, *HEMIDACTYLUS TURCICUS* (SAURIA; GEKKONIDAE) IN NORTHWESTERN ARKANSAS

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ABSTRACT

The Mediterranean gecko, *Hemidactylus turcicus*, is a small nocturnal lizard introduced into the U.S. A stable population on the campus of Westark Community College in Fort Smith, Sebastian County, Arkansas represents the northernmost U.S. population presently known. We report data on microhabitat usage, feeding behavior, reproduction, and activity patterns. This gecko is active on the outside of buildings during warm months of the year and occasionally inside buildings during the winter. It is most abundant on buildings with many crevices that are used as daytime retreats. It avoids direct illumination of artificial light and usually perches at heights greater than 7.5 meters. Geckos are not territorial during their nocturnal foraging period and employ a sit-and-wait tactic to capture insect prey. Eggs are laid in mid-June and hatch in mid August; this reproductive season is later and shorter than it is in more southern populations. Communal nesting may be employed. A nightly bimodal activity pattern was observed with peaks of activity at 2300 and 0300 after which activity declined rapidly.

INTRODUCTION

The Mediterranean gecko, *Hemidactylus turcicus*, (Gekkonidae), is a small, nocturnal lizard native to the Mediterranean area. It has been introduced into the western hemisphere and has colonized many areas; typically inhabiting buildings and other structures. In the United States, it occurs in scattered populations along the Gulf Coast from Florida to Texas, and in Arizona (Robinson and Romak, 1973; Davis, 1974; Conant, 1975). There is also a population in northern Texas (Selcer, 1986) and one in Norman, Oklahoma descended from released animals (Sievert and Sievert, 1988).

A population of *Hemidactylus turcicus* has existed on the campus of Westark Community College in Fort Smith, Arkansas (Sebastian County) since at least 1972 (T.M.Buchanan, *pers. obs.*). This is the northernmost U.S. population recorded and is the first recorded for Arkansas (Paulissen and Buchanan, 1990). There are only a few studies of the natural history of *H. turcicus* and these were on populations in the southernmost parts of the U.S. range (Rose and Barbour, 1968; Selcer, 1986, 1987). Data collected from a northern population add to the natural history information available for *H. turcicus* and permit comparison with southern populations which may help elucidate the factors that limit the range of this species.

MATERIALS AND METHODS

The central campus of Westark Community College occupies approximately 8 ha in northeastern Fort Smith. The ten buildings are one or two stories tall and are constructed of brick and cement; all have outside lights. Geckos were found on all buildings except the library which was built in 1987. Geckos were active on outside walls at night and generally hid during the day; they were occasionally found inside buildings during both day and night.

Most observations were made of geckos inhabiting the Science Building, a two story brick building with a large lecture room addition made of stucco and small rock. The south side of the building faces a lighted parking lot and a greenhouse is connected to the middle of the wall. The north wall faces an unlighted lawn. The east and west walls both have doors and are lit by outside lights on the building; there is also a lighted entrance on the south side.

Data were collected in September and October 1988 and April through June 1989. Additional observations made over several years are also reported. Geckos were censused three to five times a month between 2130 and 2330 CDT. These censuses consisted of walking slowly around the building and locating geckos with a flashlight. For each gecko seen, the following data were recorded: time, exposure (north, south, east, west), approximate height on building (<1.5 m, 1.5-4.5 m, 4.5-7.5 m, >7.5 m), amount of illumination on the lizard (total darkness, partial illumination, full illumination, or illumination from a light fixture upon which the gecko was resting), and substratum (brick, stucco and rock, cement, glass). The entire nocturnal activity pattern was quantified on 4-5 June 1989 by counting lizards at the beginning of each hour from 2000 to 0600 CDT. Data on snout-vent length (SVL), weight, and reproductive condition of females were obtained by capturing geckos from several buildings during fall 1988 and spring 1989. All lizards were examined at the time of capture and released.

RESULTS AND DISCUSSION

Adult male and female geckos did not have significantly different SVL in Fall 1988 (mean ± 1 SD: males 51.9 mm ± 2.30, n=8; females 50.4 mm ± 7.74, n=8; t-test P=0.31). Measurements were therefore pooled for the 1989 sample (mean SVL 54.1 mm ± 3.64, n=22; mean weight 3.5 g ± 0.81, range 2.3-4.5 g, n=13). These SVLs are similar to those reported for geckos in Florida (Frankenberg, 1984) and Texas (Selcer, 1986).

Geckos were more abundant on buildings with outside features that could be used as daytime retreats such as fuseboxes, pipes, vents, plates supporting light fixtures, and crevices formed at the angles where walls come together. Buildings that had relatively few of these features had fewer geckos. Geckos on the Science Building occupied some microhabitats more than others (Table 1). They were found less frequently on the south wall than other walls despite the fact that this wall was longer than either the east or west walls. This is probably because geckos avoid exposure to direct illumination. Geckos usually moved to cover when exposed to a flashlight beam and only 1% of geckos were found in direct light (Table 1). The south wall of the Science Building is well illuminated; the few geckos seen on the south wall were on or near the greenhouse which cast shadows in which the geckos could be found. The majority of geckos were at heights of greater than 4.5 m, very few were found 1.5 m or

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lower; probably because most of the daytime retreats were located higher up on the Science Building. Nearly 75% of the geckos perched on brick and most of the remainder were on stucco and rock. Geckos were seldom found on glass, metal, or smooth cement possibly because these surfaces do not provide good footing. When these smooth surfaces are omitted from consideration, the abundance of geckos on brick and stucco parallels the relative area of these two substrata on the Science Building.

Table 1. Distribution of Mediterranean geckos among features on the Science Building on the campus of Westark Community College. Percentages refer to the percentage of geckos found associated with that feature, N=100 observations.

EXPOSURE	HEIGHT (m)	LIGHTING	SUBSTRATUM
North 20%	<1.5 7%	Total Darkness 33%	Brick 72%
East 27%	1.5-4.5 24%	Partial Light 55%	Stucco 22%
South 18%	4.5-7.5 31%	Direct Light 1%	Cement 1%
West 35%	>7.5 38%	Light Fixture 11%	Glass 5%

Geckos were occasionally found on light fixtures projecting from the walls of the Science Building. The lights were designed to shine light vertically but not horizontally so a lizard perched at the base of the light was not illuminated. Presumably geckos near lights were hunting insects, though heat from light and the crevice formed by the attachment of the light to the wall may also attract geckos.

Other studies suggest that male geckos are highly territorial and defend preferred foraging areas (Behler and King, 1979); however, there was no evidence of territoriality or agonistic behavior among geckos in this study. Geckos were often found very close together, sometimes within two body lengths of each other. Similar results were noted in a study of *H. turcicus* in Florida (Frankenberg, 1982; 1984) in which there were very few agonistic interactions during the night foraging period and geckos were often found together in groups of three to five. He also noted that vocal activity, presumably a form of social communication, occurs in late afternoon while lizards are still in daytime retreats and that this species exhibited male dominance. It is not known if this is true for the Westark population.

The Mediterranean gecko is a classic sit-and-wait forager (Huey and Pianka, 1981). Most geckos appear to move little during their night activity period; it is common to find a gecko in the same spot one or two hours after initial observation. One gecko observed during the all night census stayed within an area of about 900 square cm for six consecutive hours. Prey capture involves moving slowly to within two centimeters of an insect then quickly rushing at it and catching it in the mouth. Though no diet studies were made, several geckos had 2 cm moths in their mouths. Moths are attracted to lights but some cease flying and rest on walls one to two hours after sunset and so are available to geckos.

Only two gravid females, indicated by large eggs seen through the transparent ventral skin, were captured during spring 1989. The first was found on 28 May and during handling, the tail was accidentally broken making this female easy to identify since no other female found during the study had a broken tail. She was recaptured on 9 June and was still gravid; the two eggs had acquired shells as indicated by their white color visible through the skin. On 23 June she was recaptured again and no eggs were present. The second gravid female was captured only once on 9 June; two large white shelled eggs were visible in her abdomen. These observations suggest that oviposition in the Westark population occurs in mid-June. Hatchlings appeared the third week of August in 1988 and 1989 and the second week of August in 1990. This indicates an incubation period of seven to eight weeks, slightly longer than the 40 day incubation period reported in a Louisiana population by Rose and Barbour (1968). The entire reproductive season appears to be slightly later in the Westark population than in southern populations; Selcer (1986) reported most hatching occurs in July in southern Texas, and Rose and Barbour (1968) reported the reproductive season as April to August in Louisiana. Previous studies indicate *H. turcicus* females produce two and perhaps three clutches a year in southern populations (Rose and Barbour, 1968; Selcer, 1986; 1987). We do not know if the Westark geckos produce multiple clutches, however, a gravid female was caught on 7 August 1987 suggesting either a second clutch or a late first clutch is produced.

One nest was located in June 1986 between two bales of peat moss inside the greenhouse. There were six eggs, five of which were healthy (the sixth was dried). Because *H. turcicus* produces two eggs per clutch (Selcer, 1986), the presence of six eggs in one nest indicates communal nesting. Southern populations of this species also nest communally (Davis, 1974; Trauth, 1985; Selcer, 1986; Dundee and Rossman, 1989).

The hourly activity of *H. turcicus* on the Science Building on 4-5 June is shown in Figure 1. Lizards were not active until after sunset. Peak activity occurred from 2300-2400 and remained high to a second peak at 0300-0400; after 0400, lizard activity dropped rapidly so that all geckos had retreated to daytime retreats before sunrise. The bimodal activity pattern of the Westark population is reminiscent of that of diurnal lizards in summer (Kay, 1972; Vitt and Ohmart, 1977; Paulissen, 1988). However the second peak in diurnal lizard activity patterns is correlated with the drop in ambient temperatures to within the "preferred temperature" range during the late afternoon. The ambient (air) temperature profile did not parallel the gecko's bimodal activity pattern (Fig. 1) suggesting that temperature was not the primary determinant of activity patterns. The pattern of activity observed in the Westark population differs from that observed in other populations. In Florida, peak activity occurred between 2000 and 2200 and all activity ceased by 2400 (Frankenberg, 1984); in Louisiana peak activity occurred just after dark (Rose and Barbour, 1968). These differences may reflect seasonal alterations in activity patterns; the data from Florida were collected in September and the Louisiana data were collected over several months.

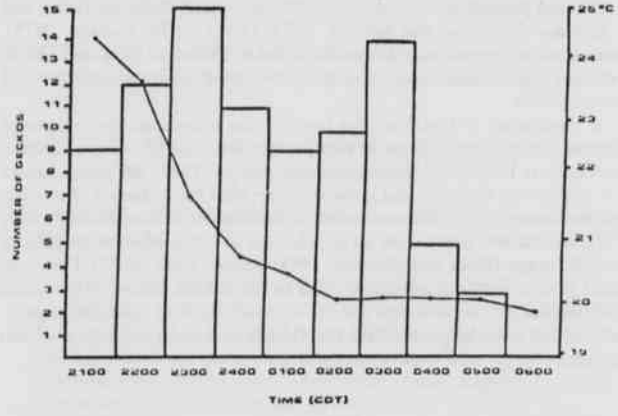

Figure 1. Night activity pattern of the Mediterranean gecko on the Science Building on the night of 4-5 June 1989. Number of geckos is shown by the histogram bars using the left vertical scale; air temperature is shown by the line using the right vertical scale. Air temperature was recorded at the beginning of each hourly census. Sunset was at 2040; sunrise at 0610.

In spring 1989, geckos were first seen on the outside of buildings on 18 April; they remained active outside until about the first week of October. During the winter, juvenile geckos were occasionally encountered inside heated buildings, usually in secluded places such as janitor's closets and behind cabinets. The number of geckos seen during the winter was much lower than the number seen on outside walls during the warmer months. This contrasts with southern populations of *H. turcicus* which may be active more or less year round, though activity is reduced during the winter (Rose and Barbour, 1968; Davis, 1974; Selcer, 1986).

Overall, the natural history of the Mediterranean gecko population at Westark Community College is very similar to that of other populations. The major differences are that the Westark geckos reproduce slightly later in the year and are less active in the winter than southern conspecifics. The Mediterranean gecko's ability to live on and in buildings should allow it to become established in any city in Arkansas to which it is introduced.

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GROUNDWATER HYDROLOGY OF A POPULATION OF *LINDERA MELISSIFOLIA* IN ARKANSAS

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ABSTRACT

Groundwater hydrology was monitored from October through August in and around a bottomland forest pond containing *Lindera melissifolia*, pondberry. The study site exhibited a series of low ancient dunes and depressions, with seasonal ponds in the depressions. Ponds showed no surface inlets or outlets. Shallow wells were made and soil cores removed along a transect from the top of one dune across the pond to a lower dune. Piezometers were installed in the wells and groundwater levels monitored. Soil core samples were analyzed to determine particle size distribution at soil profile positions selected during field analysis. It was shown that a subsurface hydrologic gradient exists between surrounding dune slopes and the pond bottom, delivering groundwater to the pond during the season when precipitation exceeds evapotranspiration. The hydrologic gradient was shown to be substrate-dependent.

INTRODUCTION

Lindera melissifolia has been declared a federally threatened species by the U.S. Fish and Wildlife Service and endangered in Arkansas. The U.S. Forest Service considers it a "rare" species and included it in a study of rare plants in the southeastern states (Kral, 1982). In Arkansas, only a few populations of pondberry in three areas of the northeastern part of the state are known. These populations only occur in association with temporary ponds in depressions between dunes formed from glacial outwash (Saucier, 1978). Ponds are typically well isolated from each other, due to natural topography and to agricultural modification of the landscape (Wright, 1989). Survival of the species requires that existing stands maintain themselves and if possible spread to other ponds.

Knowledge of the groundwater hydrology of wetland areas in which pondberry is found in Arkansas, as well as other freshwater wetlands is limited (Good, *et al.*, 1978; Pomeroy, 1979). Despite the recognized importance of the hydrologic regime to the survival of all species occupying the wetland habitat, groundwater hydrology is often the component of the wetland ecosystem not thoroughly investigated. The importance of the hydrologic regime to the survival of all species occupying the wetland habitat is now being realized (LaBaugh, 1986; Clairaiu Jr. and Kleiss, 1989).

Three most common assumptions concerning groundwater movement relative to ponds are: 1) the water table is a subdued replica of the land surface, 2) the water table in areas between ponds has a uniform slope, and 3) ponds recharge groundwater (Winter, 1986). However, studies of groundwater flow relative to topographic depressions by Meyboom (1966) and Freeze (1969) indicate that groundwater flow systems are much more complex than these assumptions indicate. Each depression in the landscape has a local flow system that is superimposed on the regional system (Mills and Zwarich, 1986).

The primary source of recharge in many wetland areas is from infiltration of precipitation (Bedinger, 1980). Surface flows may be too slow to observe easily (Hammer and Kadlec, 1986). Subsurface flow is then generated by rapid infiltration of rain and the associated increase in soil hydraulic conductivity (Pearce, *et al.*, 1986). The nature and properties of the soils in and surrounding the wetland, as well as those of underlying deposits, are important because of the relationship between soil characteristics and the movement of water (Carter, 1986).

Because it is a wetland species, pondberry is subject to alterations in hydrology. At present, little is known about the hydrological characteristics of the areas in which it is found. In order for existing stands of pondberry to maintain themselves and spread to other ponds, the hydrologic elements of their present habitat must be determined. The purpose of this study was to determine the groundwater hydrology of one such location in Arkansas. From these data, other possible areas can be located to find additional stations suitable for supporting the species. More importantly, acquisition and management decisions may be guided by the hydrological findings.

STUDY SITE

The site for this study is located in Woodruff County, Arkansas. The area exhibits a series of low, sandy dunes and depressions. The depressions form natural ponds, which are seasonal. No surface inflows or outflows were evident for the pond studied.

Soil series classifications for the area are Tuckerman, Beulah, and Bruno fine sandy loams. These soils are classified as hydric, meaning they remain saturated too far into the growing season to permit cropping (Wright, 1989). Bedding of the subsoil is such that well drillers indicate they go through various clay bands for the first 10 meters of depth (Neal Harris, United States Soil Conservation Service, personal communication).

The pondberry stand at this site is about 75 m^2 in area with an average density of 5 stems m^{-2} (Wright, 1988). It is located on the southeast berm of the depression and extends into the pond approximately 2 m. The pond is approximately 59,000 m^2 in area, and is vegetated by a closed-canopy bottomland hardwood forest.

Soil characteristics in and around the pond contribute to acquisition and retention of pond water. Although there was no evidence of surface drainage into the pond, abrupt transition to lenses of finer particle size, along with the presence of considerable clay and silt, would be expected to contribute to ponding (H. Don Scott, personal communication cited in Wright, 1989). Preliminary exploratory cores to 90 cm taken in 1988 by Larry Ward of the U.S. Soil Conservation Service in Little Rock, Arkansas

indicated some banding of layers according to particle size, including bands with considerable clay content. Mottling and concretions in the lower parts of the cores were indications of frequent flooding (Wright, 1988).

The pond margin showed no evidence of disturbance, but the fields surrounding the depression were planted in crops until March 1989. At that time, the landowner abandoned tillage around the site area and planted a buffer of pine trees around the depression containing the study site.

MATERIALS AND METHODS

Since the principal hypothesis was that the pond could be recharged by groundwater from higher ground, a transect was established from the top of a dune on the west side of the pond to the pond bottom. Five wells were drilled along this transect. Two additional wells were drilled on the pond bottom. Relative well depths and locations are shown in Figure 1. Wells 1-7 were drilled in August 1988.

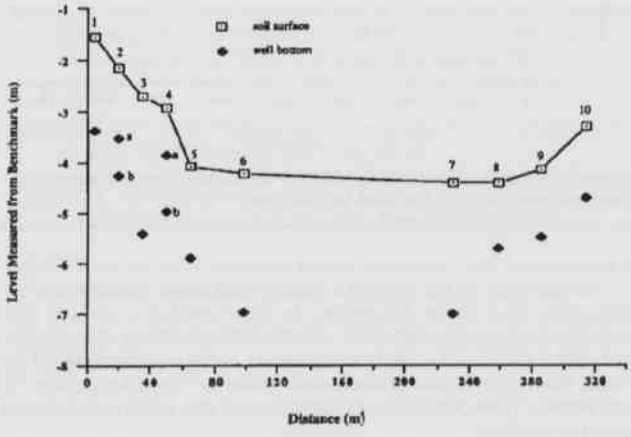

Figure 1. Depth of placement of wells in and around the pond relative to each other. Wells #5-7 are on the pond bottom.

After the soil core sample had been taken, piezometers were installed in the wells to allow for groundwater level monitoring throughout the wet season. PVCpipe having an outside diameter of 3.8 cm was used to construct the piezometers. A small amount of 2-3 cm gravel was placed in the bottom of each well prior to installing the piezometer. The piezometer was fitted with a removable cap to prevent entry of extraneous material. The piezometers allowed the level of the water table to be determined at intervals throughout the wet season (Reeve, 1986). Rainfall data for the area were obtained from the National Oceanic and Atmospheric Administration (NOAA, 1988; NOAA, 1989). The weather station is located approximately 4 km southwest of the study site.

The pond perimeter was then surveyed with a builder's level to determine the lowest point. After the lowest point was determined, another transect was established on the lowest (east) side of the pond. Three more wells numbered 8-10 were drilled along this transect (Fig. 1) in January 1989.

Water levels in the wells were monitored from October 1988 to August 1989 to determine groundwater fluctuations. Pond surface levels were also monitored during the same time period. Visual analysis of the soil at the time the soil cores were taken at well #2 and well #4 suggested the presence of perched water tables. At these two locations, an additional piezometer was installed to the depth of these suspected perched water tables, and next to the original piezometer. The original piezometers were designated B, and the new ones A.

The core samples were analyzed at the site by the United States Soil Conservation scientists. Cores of soil were also analyzed in the lab by screening and soil hydrometry (Brower and Zar, 1984) to determine particle size distribution at profile positions determined during field analysis.

RESULTS

Soils were primarily fine sandy loam, with bands of increased clay content (Fig. 2). These bands of increased clay content will be referred to as lenses. Wells #5, 6, and 7 showed evidence of strong gleying. These three wells were located on the bottom of the pond.

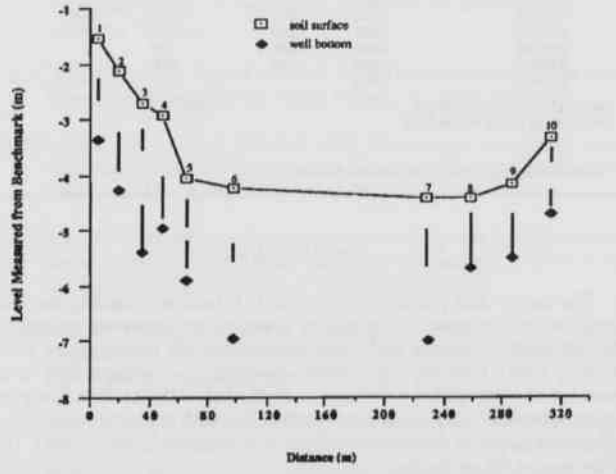

Figure 2. Abrupt increases in the clay content of the soil in each well are shown relative to each other. The depth below the soil surface of these layers is also shown. These layers of increased clay content in the soil were determined by soil particle size analysis.

Wells #2a and #4a had a high clay content at the depths they were placed, as hypothesized. The clay content at the bottom of these two wells was higher than in the soil above or below them. This was verified by the soil particle size analysis of these two wells. When correlated with monthly rainfall data, water was shown to perch above these layers with increased clay content after a rain. A layer with increased clay content was also found to be present in the samples taken from under the pond itself. Well #7 demonstrated one layer that was primarily clay.

Groundwater levels were also recorded. The soil at well#8 was saturated from February 13, 1989 through May 27, 1989, with standing water extending as much as 15 m. up the dune slope away from the pond bottom. As the pond water level dropped, saturation at well #8 decreased.

The pond contained water by November 26, 1988. While the water level had decreased, there was still water in the pond at well #7 on July 22, 1989.

STATISTICAL ANALYSIS

Depth to the groundwater level from the surveyed benchmark was regressed with the distance between wells. Regressions were calculated for each date that groundwater levels were measured. Only those dates on which sufficient data were collected were used in the analysis. The slope of the regression line indicated the direction of groundwater flow and hydraulic gradient (Table 1). The correlation coefficient was also determined to describe the tendency for distance between wells and depth to the water table to covary. The absolute value of the coefficient indicated the strength of that tendency to covary.

Table 1. Hydraulic gradient and correlation coefficient analysis for sample dates with sufficient data.

Date	Hydraulic Gradient wells 1-5	wells 8-10	Correlation Coefficient wells 1-5	wells 8-10
11/26/88	-.020			
12/18/88	-.009		.599	
1/03/89	.006	-.008	.559	
1/16/89	-.008	-.030	.778	
1/30/89	-.010	-.020	.964*	
2/13/89	-.020	-.001	.865	.386
2/27/89	-.020	.00	.974*	.386
3/13/89	-.010	.002	.935*	.397
3/27/89	-.010	.003	.945*	.280
4/07/89	-.020	.005	.957*	.400
4/15/89	-.010	-.002	.817	.650
4/29/89	-.005	-.002	.634	.240
5/13/89	-.005	-.001	.559	.048
5/20/89	-.010	-.004	.620	.274
5/27/89	-.005	.00	.396	
6/10/89	-.003	-.001	.274	.984*
6/17/89	-.008	-.020	.721	
6/24/89	-.010	-.020	.783	
7/08/89	-.006	-.020	.500	
7/22/89	-.010			
Soil Surface Slope Wells 1-5			-.040	
Soil Surface Slope Wells 8-10			.020	

* Statistically significant at 95% confidence level

DISCUSSION

The nature and properties of the soils in and surrounding the wetlands, as well as those of underlying deposits, are important because of the relationship between soil characteristics and the movement of water (Carter, 1986). One important factor modifying soil permeability is the presence of permeability variations at depths below the surface. The presence of permeability variations directly beneath the depressions also affects the nature of depression focused flow systems (Lissey, 1971). This is the case at the study site.

Field soil data indicated the presence of primarily fine sandy loam soil with a clay content of 0-4%. However, clay lenses were present in soil samples from all ten wells (Fig. 2). The clay content in these samples increased to as much as 15% at several depths. These clay lenses were at a higher elevation outside the depression edge than in the depression. The clay lens under the pond itself appeared to be continuous across the pond bottom at about 5 m below the benchmark. The clay lens below the depression would be an effective aquiclude (Johnson, 1942). As water enters the depression, the slower permeability of the clay lens would cause the water to pond above it.

In the late fall and winter months, rainfall is much higher than evapotranspiration. This results in a greater input (rainfall) than output (evapotranspiration plus internal drainage) causing the soil profile to become wet and water to pond on the clay lens. Since the depth in the profile to the clay lens increases toward the pond, the water ponded above the clay lens establishes a horizontal pressure gradient. As a result of this gradient and the more rapid saturated hydraulic conductivity in the coarser textured horizon, saturated flow of water occurs above the clay lens toward the pond (Lissey, 1971; Pearce, *et al.*, 1986). This groundwater exchange must be primarily lateral rather than vertical (Schalles and Shure, 1989). Water flow was lateral into the pond from the west side during the late fall and winter. Statistical analysis of regression for the sample dates also indicates this (Table 1). Some groundwater outflow is also shown at well #8.

During the late spring months, water loss becomes greater than input as evapotranspiration increases. As the depth of ponded water decreases, transport of water to the pond is reduced. When flow has become significantly reduced, the soil above the clay lens becomes largely unsaturated and the hydraulic gradient will be low. This pattern was demonstrated at the study site.

Clay lenses closer to the surface allow for the formation of perched water tables. Wells #2a and #4a were placed at depths where the field soil analysis indicated clay lenses existed. At these two locations perched water tables formed after a rain due to the infiltration of the water through the soil vertically and perching of the water on the layer of soil with increased clay content (Fig. 3). Water remained perched several days. These perched water tables delivered water by lateral movement into the pond. Data also indicated a clay lens that was a possible perched water table at well 10. These shallow clay lenses were approximately 0.44 m thick.

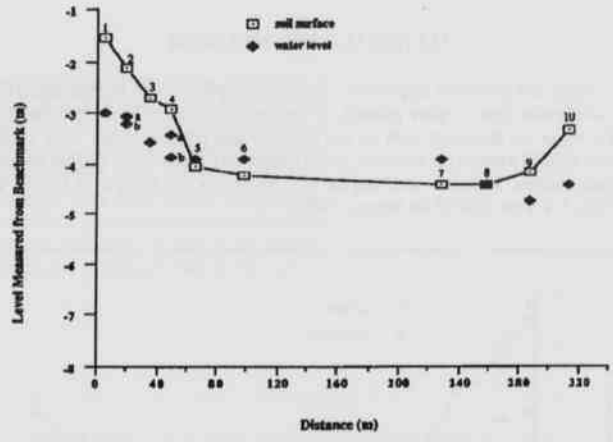

Figure 3. Groundwater levels for 2/27/89 are shown. Perched water tables were present at wells 2A and 4A at this time.

Groundwater in the study site area should move laterally into the depression. Once in the depression, the water ponded on the clay lens under the depression surface. This contributed to the filling of the depression. Some outflow of groundwater occurred on the low (east) side of the pond. Water also formed perched water tables on clay lenses nearer the soil surface. These perched water tables formed after a rain and dissipated after several days.

While groundwater hydrology of this area appears evident on a local scale, the total flow system of the area may be much more complex. Further studies on how the regional flow system affects this local system are necessary before a complete analysis of the groundwater hydrology of the area in which *Lindera melissifolia* is located can be made.

ACKNOWLEDGMENT

Larry Ward and Neal Harris of the United States Soil Conservation Service assisted in drilling the core samples and field analysis of the soil. Design for the piezometers was obtained from the University of Arkansas Agronomy Department, in cooperation with Dr. Don Scott. This study was supported by grants from the Arkansas Nongame Committee and the Arkansas Native Plant Society.

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DISTRIBUTION AND HABITAT UTILIZATION OF THE FOUR-TOED SALAMANDER, *HEMIDACTYLIUM SCUTATUM*, IN THE OUACHITA MOUNTAINS OF ARKANSAS

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ABSTRACT

Four-toed salamanders in Arkansas represent a disjunct population separated from their main range in the eastern United States and Canada. Until recently, the distribution of this species was documented by a few individual specimens collected or observed from widely spaced localities which has resulted in its being considered rare and vulnerable. Recent investigations of distribution and habitat utilization indicate this species may be more common than previously believed, but also reaffirms the need to protect riparian habitat, springs, ponds, woodland seeps and other preferred, moist habitats containing mossy areas used as primary egg deposition sites.

INTRODUCTION

The four-toed salamander, *Hemidactylium scutatum*, is one of Arkansas' disjunct amphibians, separated from its primary range in the eastern United States and Canada (Conant, 1975). *Hemidactylium* is considered rare by the Arkansas Natural Heritage Commission (ANHC) and is considered a sensitive species by the United States Forest Service (USDA-Forest Service 1990a). Extensive statewide investigations of the herpetofauna within state parks by the Arkansas Herpetological Society (Heath *et al.*, 1988) and intensive herpetofaunal investigations in the Ozark National Forest (Schuier *et al.*, 1972) and Coastal Plain (Bacon and Anderson, 1976) failed to document this species. Until 1986, when Trauth and Caldwell reported a single specimen from Cleburne County in the Ozark Mountain region, the range of this species in Arkansas was thought to be restricted to the Ouachita Mountains (Reagan, 1974; Smith, 1984).

The presence of *Hemidactylium* within the Ouachita Mountains was first reported by Hurter and Strecker (1909) when two specimens were collected from the general vicinity of Hot Springs in Garland County. Black and Dellinger (1938) reported one additional specimen collected by Hurter from Hot Springs between 1909-1912 but no new localities. Nineteen years later, Dowling (1957) reported specimens had been collected in Hot Spring, Howard and Polk counties, but Reagan (1974) described the localities in Hot Spring and Howard counties as erroneous. The Polk county location was verified with a specimen deposited in the University of Arkansas Department of Zoology collection. Reagan (1974) gave the range for *Hemidactylium* as Garland, Clark, and Polk counties but did not provide a location or disposition of the Clark County record. Reagan (1974) reported the collection of a single specimen from a boggy area adjacent to the Cossatot River below Duckett Ford in Howard County, an area now inundated by Gilham Lake. Smith (1984) reported the range of *Hemidactylium* as Garland, Howard, Montgomery, and Polk counties. The addition of Montgomery County was based on two, unpublished 1983 observations of individual specimens recorded in the ANHC database. No explanation was given for the removal of Clark County. Interestingly, during the 80 year period between 1909 and 1989, only 18 specimens of *Hemidactylium* had been reported in the literature or their locations documented in the Arkansas Natural Heritage Commission database. In 1990, Trauth *et al.* discussed reproduction in *Hemidactylium* and reported 42 specimens collected from Garland and Montgomery counties. Many of the specimens reported by Trauth *et al.* (1990) were collected during this study. And recently Trauth and Cochran (1991) recorded a specimen from southwestern Garland County.

From October, 1983 through March, 1991 we conducted a general survey of salamander species distributions in the Ouachita Mountain region of west-central Arkansas. One of the species of specific interest was *Hemidactylium*. The purposes of the present study were to locate additional specimens of *Hemidactylium* in an effort to better define distribution within the Ouachita Mountains of Arkansas and to more precisely determine habitat utilization in an effort to provide resource managers better information with which to make decisions.

STUDY AREA

The Ouachita Mountains have been folded, vaulted, and uplifted through geologic time, and exhibit an east-west, ridge and valley landscape with elevations ranging from 80 to 860 m above sea level. The soils, developed from sandstone, shale, novaculite and chert, are dry to droughty and range in texture from loam to clay (Pell, 1983). Second-growth (50-70 years old) mixed hardwoods *(Quercus/Carya)* occur on more mesic north slopes with dryer south slopes vegetated by second growth shortleaf pine *(Pinus echinata)* forest types, particularly on Ouachita National Forest lands. Interspersed among National Forest lands are a number of small communities, timber company lands primarily vegetated with second and third growth loblolly pine *(Pinus taeda)* and mixed hardwood forest types, and private residences and cattle and poultry farming operations with much land in pasture. Timber harvest activities have created a very diverse landscape, both horizontally and vertically, ranging from early successional seral stages to areas of older growth. The result of this intermingled land ownership has been to create a habitat mosaic.

The region contains a significant number of rivers and streams, several thousand wildlife waterholes and ponds of various sizes, and numerous lakes with associated riparian habitat. Most first and second order streams and some third and fourth order streams may have occasional periods of intermittent flow during dryer summer and fall months; however, most third and fourth order streams are perennial. South of the Ouachita River, many streams of all orders are perennial due to springs in their upper reaches. Many streams (both perennial and intermittent), wildlife ponds, spring runs and catch basins, and some unique communities such as woodland acid seeps, contain pools and segments heavily vegetated with mosses (USDA-Forest Service, 1990b).

MATERIALS AND METHODS

Most observations/collections of *Hemidactylium* were made while road cruising paved highways during rainy periods in fall, winter and spring months. A majority of state highways in Garland, Montgomery, Perry, northern Pike, Polk, Scott and Yell counties were cruised at least once during the study period. Two sites, one in Garland County and one in Polk County, were particularly productive and were road cruised on more than one occasion and in different years. Salamanders were captured by hand, placed in zip-loc bags with moist paper towels, and retained in ice chests until road cruising activities for the evening ceased so that specimens could be refrigerated awaiting transport.

Ground search activities were concentrated in flood plains of perennial and intermittent streams, spring and spring runs, mossy areas in other moist conditions, and beneath structural habitat components such as logs and rocks. Specimens were processed as previously described.

Hemidactylium retained as specimens were transported alive to Arkansas State University and the University of Arkansas-Little Rock, where nearly all were processed within 48 hours after capture. Individuals

served in 70% ethanol for use in associated studies of life history and reproductive biology.

RESULTS

A total of 45 *Hemidactylium* was collected/observed at 18 new locations in Garland, Montgomery and Polk counties (Fig. 1). Nineteen animals were observed during road cruising activities in October (16) and November (3), and 18 animals were observed during February (14) and March (4). Eight specimens were located during ground search activities (Table 1).

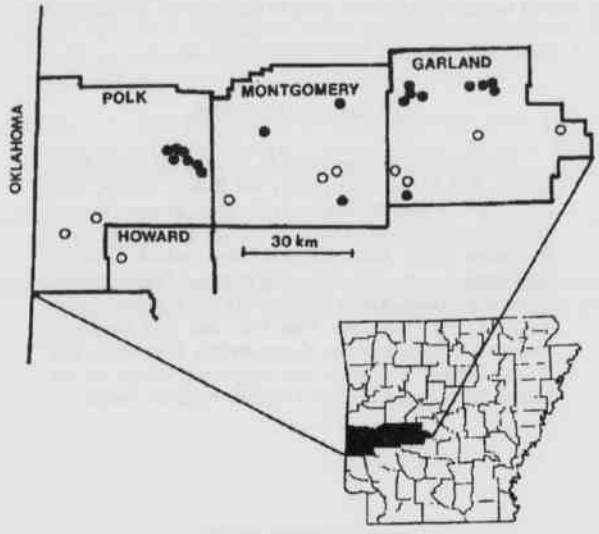

Figure 1. Distribution of *Hemidactylium* within the study areas. Closed circles represent locations from this study. Open circles represent previously known locations.

Table 1. Summary of locations where specimens of the four-toed salamander, *Hemidactylium scutatum*, were located during this study, and locations found in he Arkansas Natural Heritage Commission database (denoted by asterisk).

COUNTY	LOCATION	NO. OBSERVED	DATE	RC/GS
Garland	T1N-R19W-S31	3	10/22/86	RC
	T1N-R20W-S27	2	10/08/83	GS
	T1S-R19W-S18	1	10/22/86	RC
	T1S-R20W-S01	1	10/23/86	RC
	T1S-R22W-S10	1	07/02/90	RC
	T1S-R22W-S15	6	02/03/86	RC
		6	02/17/86	RC
	T1S-R22W-S16	1	03/21/91	GS
	T1S-R22W-S22	4	03/11/86	RC
	T2S-R17W-S18*	1	03/83	GS
	T2S-R20W-S13*	1	05/79	GS
	T3S-R22W-S06*	4	07/21/86	GS
	T3S-R22W-S17*	1	09/20/84	GS
Howard	T6S-R30W-S09*	1	02/73	GS
Montgomery	T2S-R24W-S09	1	10/17/84	RC
	T2S-R26W-S27	4	02/19/86	GS
	T3S-R24W-S10*	1	05/03/86	GS
	T3S-R24W-S17*	1	02/83	GS
	T4S-R24W-S06	1	07/09/90	GS
	T4S-R27W-S04*	1	10/15/83	GS
Polk	T2S-R29W-S36	1	10/12/84	RC
	T3S-R28W-S06	1	10/12/84	RC
		2	10/18/85	RC
		1	02/02/90	RC
	T3S-R28W-S07	1	10/12/84	RC
		1	11/11/85	RC
	T3S-R28W-S08	2	10/12/84	RC
		1	10/18/85	RC
		1	11/11/85	RC
	T3S-R28W-S09	1	11/11/85	RC
	T3S-R28W-S16	1	10/19/85	RC
	T3S-R28W-S23	1	10/19/85	RC
	T4S-R31W-S25*	1	04/53	GS
	T3S-R32W-S02*	1	06/81	GS

Denotes method of collection: GS= Ground Search, RC= Road Cruising

Other species of salamanders observed during road cruising activities on nights when four-toed salamanders were observed included *Ambystoma annulatum, A. maculatum, A. opacum, A. texanum, Eurycea multiplicata, Notophthalmus viridescens, Plethodon albagula,* and *P. serratus*. Species captured from leaf litter and beneath logs along with *Hemidactylium* during ground search activities included *Desmognathus brimleyorum, E. multiplicata,* and *P. albagula*.

DISCUSSION

Ground search activities were conducted in numerous locations throughout the study area with four sites yielding eight *Hemidactylium*. For example, on 8 October 1983, a male and female were found together beneath a flat rock in a sand and small gravel portion of Blakely Creek (Garland County) where stream depth was approximately 7 cm. The pair was located a few m from a small spring-run vegetated with mosses. The riparian area containing the stream was composed of a narrow strip of vegetation 25 m wide bounded by roads on two sides, fields intermingled with pine and hardwood timber, common in the area, and a residence within 75 m. Four-toed salamanders breed in the fall which may account for the occurrence of both sexes at this site (Johnson, 1987).

Three *Hemidactylium* were discovered beneath moss growing on a decayed portion of a shortleaf pine branch partially submerged in a small seepage pool (45 cm sq. X 10 cm deep) in an upland intermittent drain vegetated by oak and hickory tree species. The timber stand surrounding the pool was relatively open and composed of hardwood and shortleaf pine trees 65 years old. This stand had been thinned during timber harvest activities two years earlier but had received no further silvicultual treatments. Further examination of the general area did not yield addition pools. A lack of suitable nest sites has ben suggested as a possible factor influencing communal nesting among female *Hemidactylium* (Breitenbach, 1982). An additional specimen was discovered in the same timber stand about 150 m away among hardwood leaves at the bottom of a small pool in a boggy area containing mosses, hardwoods, and overgrown with greenbrier *(Smilax)*. This partially shaded site was located within 5 m of a major county road bordered by extensive private pasturelands.

Two other specimens discovered during ground search activities were both found in timber stands with a predominant shortleaf pine overstory. At one site, a salamander was found beneath a log in a stand with an extremely dense hardwood midstory. The other salamander was collected from hardwood/pine leaf litter accumulated behind a large shortleaf pine branch at the edge of a small seepage pool in an intermittent upland drain. The seepage area and pool were at the head of a road drainage tile and were within 5 m of a major forest road. The surrounding timber stand was 56 years old and very open as the result of commercial timber harvest to thin the stand (1983) and wildlife stand improvement-midstory removal harvest (1987).

Ten of the occurrence records for *Hemidactylium* contained in the ANHC database include some information on the habitat in which the animals were observed. Virtually all reported animals were found beneath logs or beneath moss mats growing on the surfaces of logs, in the floodplain of a stream, or adjacent to a spring or creek. Similar observations have been made regarding habitat use by *Hemidactylium* throughout its range (Bleakney and Cook, 1957; Carter, 1968; Martof, 1955). Most of the nests observed by Johnson (1987) in Missouri have been along small, fishless creeks in thick mats of mosses. Examination of moss mats in fishless streams in the Ouachita Mountains has shown these sites to support large populations of isopods which may provide a significant prey resource.

Use of small ponds with abundant logs and shallow areas with moss mats and thick grasses and rushes along the shore appear to be a significant nesting habitat for *Hemidactylium* in the northern portion of its range (Harris and Gill, 1980; Wallace, 1984). None of the specimens from the Ouachita Mountains have been collected from ponds.

Road cruising activities have provided for the bulk of localities reported in this study. Two sites, one each in Garland and Polk counties, have been particularly productive. The Garland County location lies

along the county road leading to the community of Buckville. On four separate occasions, a total of 17 live *Hemidactlyium* was observed or collected within a one mile segment of road. Six salamanders were observed on each of two occasions within a nine day period, and one month later, four salamanders were seen. In addition to these live animals, several carcasses and tails, victims of automobile traffic, were observed. Examination of aerial photographs reveal a habitat mosaic consisting of many acres of open fields, seedling/sapling stands of loblolly and shortleaf pine, intermingled hardwood riparian habitat, a few stands of older pine and pine/hardwood mixed forest types, and homes or businesses. The topography of the general area within one mile of the collection site is relatively flat and contains at least 13 small ponds. The pond adjacent to the county road to which the observed specimens were moving is the result of beaver *(Castor canadensis)* activity which has created a small wetland by retaining water on the previously timbered site. Tree death from inundation and beaver foraging activity have opened up the forest canopy and resulted in an accumulation of logs, dense herbaceous plant growth, and extensive growth of mosses. Orientation of salamanders at the time of capture indicated they had traveled crosscountry through a loblolly pine plantation about 10 years old, or had traveled through the plantation using small stream channels and wet areas with abundant moss mats.

The Polk County location lies along Highway 8 near the Big Fork community. Between 1984 and 1990, a total of 14 live salamanders was collected on four separate nights in October, November and February. In addition to live specimens, numerous carcasses and severed tails were observed on the roadway indicating a considerable number of animals were moving in the area. Most of the land along Highway 8 where these collections have occurred is privately owned, and portions are grazed by livestock or maintained in hay pasture. The land is relatively flat and broken by wooded riparian strips bordering tributaries to Big Fork and Mill Creeks and contains many springs and seeps in and adjacent to the floodplain. Mosses, dense herbaceous vegetation, and decaying logs of various diameters are abundant and well distributed in the area. Adjacent Forest Service lands are, for the most part, relatively steep uplands vegetated by species characteristic of mesic north slope forest types *(Quercus/Carya)* and xeric south slopes *(Pinus/Quercus/Carya)* dissected by intermittent flow streams characterized by hardwood species typical of the Ouachita Mountain region.

Hemidactylium apparently is not adverse to traversing habitat conditions not typically considered preferred habitat. Bleakney and Cool (1957) reported brooding females in a pond isolated by railroad tracks, highways, and a cemetery, and LaPointe (1953) collected a specimen from a highway during rainy weather.

HABITAT MANAGEMENT

Habitat considerations for salamanders, including *Hemidactylium*, were included as forest management goals and objectives with standards and guidelines established to help meet these goals in the Amended Land and Resource Management Plan for the Ouachita National Forest (USDA-Forest Service, 1990b). Goals include protecting and improving habitat for sensitive species with emphasis placed on providing sensitive species habitat not found on private lands. In the case of *Hemidactylium*, forest wide standards and guides providing for the development of a mature growth pine and hardwood component, retention and/or creation of logs on a per acre basis during timber harvest activities to enhance forest floor structural diversity, and non-harvest buffer strips adjacent to intermittent and perennial streams, springs, wetlands and lakes – all important habitat components for this species. In addition, unique community types, such as woodland acid seeps that typically contain extensive areas of mosses suitable for egg deposition, are fully protected. Wildlife waterholes (ponds) are prescribed at a rate of one per 160 acres (4 per square mile) with ponds less than one-half surface acre which are not stocked with fish to provide suitable breeding habitat for native amphibians.

These proactive habitat enhancement and protection actions were developed to ensure the viability of *Hemidactylium* and other salamander species and to preclude trends toward endangerment that would result in the need for Federal listing (USDA-Forest Service, 1990b; 1990c).

Recommendations to further enhance habitat for *Hemidactylium* include: (1) prohibiting the collection of mosses from all aquatic habitats. Mosses have clearly been demonstrated to be a critical component of breeding habitat and are necessary to maintain viability for this sensitive species; 2) modification of pond construction. Ponds should be constructed to provide areas of shallow water where mosses and other dense shoreline vegetation may become established. In addition, because use of logs by this salamander indicates a need for this structural component near aquatic situations, some of the trees removed from pond excavation sites should be placed in shallow areas to facilitate use by salamanders.

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PREPARATION OF A SERIES OF N-PHENYLAMIDES OF 5-BROMO-6-CHLORONICOTINIC ACID AND 5-BROMO-2-CHLORONICOTINIC ACID

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ABSTRACT

A series of N-phenylamides of 5-bromo-6-chloronicotinic acid and 5-bromo-2-chloronicotinic acid were synthesized by treatment of their freshly prepared acid chlorides with the appropriately ring-substituted anilines. Thirty new compounds were prepared, and their structures were ascertained by elemental analyses and spectroscopic techniques. Spectroscopic trends in the infrared spectra of the two series were examined in an attempt to correlate structural and electronic effects to hydrogen bonding tendencies.

INTRODUCTION

In connection with our continuing search for dihalonicotinic acid derivatives with potential pesticidal, herbicidal, and fungicidal activity (Setliff *et al.*, 1989), we have prepared a series of N-phenylamides of 5-bromo-6-chloronicotinic acid (I) and 5-bromo-2-chloronicotinic acid (II) (Setliff, 1970). These compounds, with the dihalopyridine moiety on the carbonyl side of the amide function, exhibit a reversal of the amide linkage in comparison to previously reported benzamide and phenylurea halopyridine derivatives (Setliff and Palmer, 1987; Setliff and Rankin, 1988; Setliff *et al.*, 1989).

Thirty new N-phenylnicotinamides were synthesized with a variety of electron releasing groups and electron withdrawing groups present on the benzene ring. Having available two such closely related series of compounds, we also sought to look for any trends in their infrared spectra which could be related to the electronic effects of the benzene ring substituents.

MATERIALS AND METHODS

Acids I and II were prepared as previously reported (Setliff, 1970). The substituted anilines employed were fresh practical grade samples from either Aldrich Chemical Company or Eastman Organic Chemicals. All liquid anilines were freshly distilled. All solid anilines were used without further purification with the exception of 4-chloroaniline and 4-methoxyaniline which were recrystallized from methylcyclohexane.

Melting points are uncorrected and were determined using a Mel-Temp II capillary melting apparatus. Infrared spectra were obtained on samples prepared as potassium bromide disks using a Perkin-Elmer 1430 spectrophotometer equipped with a Model 7300 data station. Proton nuclear magnetic resonance spectra were obtained using an AC-F Brucker 200 MHz FT spectrometer with deuterated dimethyl sulfoxide as the solvent and tetramethylsilane as the internal standard. All elemental analyses were performed by Desert Analytics Organic Microanalysis, Tuscon, Arizona.

The N-phenyl-5-bromo-6-chloronicotinamide compound series (III) and N-phenyl-5-bromo-2-chloronicotinamide compound series (IV) were obtained by heating a chloroform solution of the freshly prepared acid chlorides with an excess amount of the appropriately substituted anilines. The reaction sequence is depicted in Figure 1. Dihaloacid I or II (0.50 g; 0.0021 mol) was stirred and heated under reflux with thionyl chloride (3.0 mL) for 30 minutes then cooled to room temperature. The acids completely dissolved to yield a transparent yellow solution. Excess thionyl chloride was removed from this solution under reduced pressure on a rotary evaporator (oil bath 50-60 °C). The residual viscous acid chloride was taken up in chloroform (2.0 mL) and to this mixture was added a solution of the appropriately substituted aniline (0.0050 mol) in chloroform (10.0 mL). A solid precipitate formed, and the resulting reaction mixture was heated under reflux for one hour and 30 minutes then cooled to room temperature. The solid precipitate was collected by vacuum filtration, dried and weighed, and the chloroform filtrate was saved.

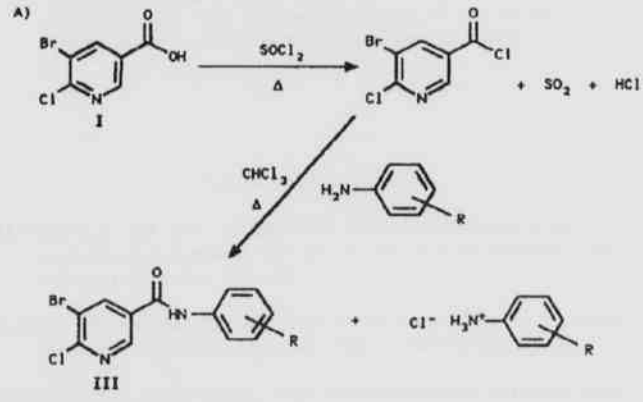

Figure 1. A) Preparation of the 5-bromo-6-chloronicotinamides and B) the 5-bromo-2-chloronicotinamides

Isolation and purification of the amide products varied according to their chloroform solubilities. Some of the amides were extremely chloroform-soluble as evidenced by the weight and water solubility of the amine hydrochloride isolated from the reaction mixture. In these instances, purification procedure A was employed as follows: The chloroform filtrate from the reaction mixture was washed with water (2 x 10 mL) followed by 10% hydrochloric acid (2 x 10 mL) and then evaporated to yield the crude amide product, which was subsequently recrystallized from aqueous ethanol.

Several amide products were insoluble in chloroform and precipitated together with the amine hydrochlorides. These compounds were purified by procedure B as follows: The precipitate from the reaction mixture was stirred magnetically in water (150 mL) to dissolve the amine hydrochloride. The residual crude amide was collected by filtration and recrystallized from aqueous ethanol.

In a few instances, the amide product was partially soluble in chloroform and was distributed between the precipitated solid and the chloroform filtrate. Purification procedure C was employed in these cases as follows: The reaction mixture precipitate was stirred magnetically in water (150 mL), and the undissolved amide product was collected by filtration. The original chloroform filtrate was washed with water (2 x 10

mL) followed by 10% hydrochloric acid (2 x 10 mL) and then evaporated to yield an additional amount of amide. The two portions of the crude amide were combined and recrystallized from aqueous ethanol.

Summaries of melting points, percentage yields, and purification procedures employed appear in Table 1 (series III amides) and Table 2 (series IV amides.)

Table 1. Percentage Yields, Melting Points, and Purification Procedures of the N-(Substituted phenyl)-5-bromo-6-chloronicotinamides.

Compound	R	Yield (%)	mp (°C)	Purification Proce
IVa	4-CH_3	89.7	158.5	A
IVb	4-Br	87.0	176	A
IVc	H	90.1	140-140.5	A
IVd	4-Cl	93.2	161-162	A
IVe	4-OCH_3	97.2	163.5-164	A
IVf	3-CH_3	89.7	156-156.5	A [a]
IVg	4-OCH_2CH_3	92.0	185.5-186	C
IVh	2-CH_3	89.7	213-214	C [a]
IVi	2,4-diCH_3	80.0	189-189.5	A
IVj	2-Cl	93.2	176.5-177	A
IVk	4-I	84.8	201.5-202	C
IVl	4-F	87.0	155.5-156.5	A
IVm	2-F	92.8	141-141.5	A
IVn	4-NO_2	80.0	221.5-222	B [b]
IVo	4-$COCH_3$	78.0	212-216	A

a.

Table 2. Percentage Yields, Melting Points, and Purification Procedures of the N-(Substituted phenyl)-5-bromo-2-chloronicotinamides.

Compound	R	Yield (%)	mp (°C)	Purification Proc
IIIa	4-CH_3	86.7	182-183	A
IIIb	4-Br	75.6	229-231	B
IIIc	H	89.2	166-166.5	A
IIId	4-Cl	75.3	212-212.5	C
IIIe	4-OCH_3	80.6	181.5-182	C
IIIf	3-CH_3	91.2	155-156	A [a]
IIIg	4-OCH_2CH_3	88.0	177	C
IIIh	2-CH_3	70.6	206.5-207	B
IIIi	2,4-diCH_3	88.0	185	A
IIIj	2-Cl	80.3	184-184.5	A
IIIk	4-I	76.1	256.5-257.5	B
IIIl	4-F	82.6	175.5-176	A
IIIm	2-F	85.5	178.5-179	A
IIIn	4-NO_2	65.0	229.5-230	B [b]
IIIo	4-$COCH_3$	59.5	237-238	C

RESULTS AND DISCUSSION

Thirty new amides, 15 from each series, were synthesized in excellent yields (usually greater than 80%). Elemental analysis of these compounds showed agreement to within 0.4% of the calculated percent compositions. Infrared spectra revealed the expected absorption bands for both the carbonyl group and amide proton frequencies. Tables 3 (series III amides) and 4 (series IV amides) summarize these infrared absorption frequencies and elemental analysis results.

Table 3. Infrared Spectral Data and Elemental Analysis Results of the N-(Substituted phenyl)-5-bromo-6-chloronicotinamides.

Compound	R	IR, (cm^{-1})		Elemental Anal., Calc'd % (Found %)		
		N-H	C=O	C	H	N
IIIa	4-CH_3	3314	1680	47.94(48.08)	3.07(3.11)	8.61(8.47)
IIIb	4-Br	3340	1678	36.90(37.03)	1.79(1.72)	7.17(7.14)
IIIc	H	3280	1642	46.24(45.94)	2.57(2.62)	8.99(8.75)
IIId	4-Cl	3354	1683	41.63(41.41)	2.02(1.87)	8.10(8.01)
IIIe	4-OCH_3	3328	1669	45.69(45.46)	2.93(2.92)	8.20(8.13)
IIIf	3-CH_3	3277	1649	47.94(47.82)	3.07(2.88)	8.61(8.49)
IIIg	4-OCH_2CH_3	3349	1667	47.27(47.02)	3.38(3.24)	7.88(7.66)
IIIh	2-CH_3	3281	1643	47.94(47.53)	3.07(3.01)	8.61(8.47)
IIIi	2,4-diCH_3	3262	1638	49.48(49.44)	3.54(3.49)	8.25(8.16)
IIIj	2-Cl	3285	1649	41.63(41.74)	2.02(1.81)	8.10(7.97)
IIIk	4-I	3332	1676	32.93(32.51)	1.60(1.59)	6.40(6.18)
IIIl	4-F	3273	1644	43.72(43.82)	2.13(1.98)	8.50(8.40)
IIIm	2-F	3287	1649	43.72(43.61)	2.13(2.02)	8.50(8.39)
IIIn	4-NO_2	3326	1685	40.42(40.26)	1.98(1.82)	11.79(11.64)
IIIo	4-$COCH_3$	3313	1674	47.55(47.81)	2.86(2.77)	7.92(7.85)

Table 4. Infrared Spectral Data and Elemental Analysis Results of the N-(Substituted phenyl)-5-bromo-2-chloronicotinamides.

Compound	R	IR, (cm^{-1})		Elemental Anal., Calc'd % (Found %)		
		N-H	C=O	C	H	N
IVa	4-CH_3	3248	1655	47.94(47.72)	3.07(3.11)	8.61(8.50)
IVb	4-Br	3240	1656	36.90(36.81)	1.79(1.76)	7.17(7.03)
IVc	H	3274	1658	46.24(46.03)	2.57(2.51)	8.99(8.72)
IVd	4-Cl	3293	1663	41.63(41.42)	2.02(2.00)	8.10(8.01)
IVe	4-OCH_3	3245	1649	45.69(45.43)	2.93(2.90)	8.20(8.06)
IVf	3-CH_3	3247	1657	47.94(48.05)	3.07(2.83)	8.61(8.50)
IVg	4-OCH_2CH_3	3253	1649	47.27(47.10)	3.38(3.29)	7.88(7.70)
IVh	2-CH_3	3239	1654	47.94(47.70)	3.07(2.94)	8.61(8.40)
IVi	2,4-diCH_3	3241	1652	49.48(49.10)	3.54(3.44)	8.25(8.18)
IVj	2-Cl	3237	1659	41.63(41.88)	2.02(1.86)	8.10(8.34)
IVk	4-I	3263	1649	32.93(32.81)	1.60(1.52)	6.40(6.20)
IVl	4-F	3292	1658	43.72(43.85)	2.13(2.05)	8.50(8.41)
IVm	2-F	3245	1665	43.72(43.70)	2.13(2.02)	8.50(8.41)
IVn	4-NO_2	3235	1649	40.42(40.32)	1.98(1.72)	11.79(11.64)
IVo	4-$COCH_3$	3269	1670	47.55(47.30)	2.86(2.70)	7.92(7.79)

Having available such a closely related series of compounds, we sought to look for any trends in their spectra which could be related to the electronic effects of the R group within the amide series III or series IV. In addition, trends which could be related to the position of the chlorine on the pyridine ring (6 position in series III vs. 2 position in series IV) for a common R substituent were also sought. We chose to compare the N-H and carbonyl stretching frequencies of crystalline samples prepared as KBr disks, since comparisons of these absorption frequencies might reveal the degree of hydrogen bonding which might be occurring in the solid state (Silverstein *et al.*, 1981).

An obvious trend noted was that the series III amides exhibited N-H stretching bands ranging from 3354 cm^{-1} (IIId) to 3262 cm^{-1} (IIIi), while the amides in series IV showed a significantly lower range of absorption frequencies (3293 cm^{-1} for IVd to 3235 cm^{-1} for IVn). The differences in frequencies between the two series for a given R substituent ranged from 100 cm^{-1} (IIIb > IVb) to 6 cm^{-1} (IIIc > IVc). The only discrepancy in the cross-series trend was the 4-fluoro substituent where IV1 > IIII by a margin of 19 cm^{-1}.

Since the change in frequencies between the two series was smallest for R = H (6 cm^{-1}), it was attractive to speculate that the presence of a substituent on the benzene ring does appreciably affect the magnitude of the N-H stretching frequency. However, attempts to correlate the N-H stretching frequencies within each series with electronic effects of the R substituent were unrewarding. A Hammett plot of these N-H frequencies versus the 3 and 4 position R substituent constants (Exner, 1988) showed no linearity in either amide series. It is noteworthy that since N-H stretching frequencies are influenced by other factors such as vibrational coupling and Fermi resonance, localized substituent effects on the N-H bond are difficult to measure (Exner, 1988). This complication may be responsible in part for our poor correlations.

Observations of various carbonyl stretching frequencies revealed that the series III amides as a group exhibited a broader range of frequencies (1685 cm^{-1} to 1638 cm^{-1}) than did the series IV amides (1679 cm^{-1} to 1649 cm^{-1}), but there was no clear trend in the cross-series comparisons. In fact, in seven of the 15 cases the series III compounds showed a lower carbonyl stretching frequency than the series IV compounds. In addition, there was no apparent correlation of these frequencies with Hammett substituent constants within either series.

One attractive conclusion of the observed spectral trends is that the overall lower N-H stretching frequencies in the series IV amides suggest stronger solid state hydrogen bonding in this series than in the series III amides. The inconsistencies in the carbonyl stretching frequencies could be explained by the fact that several other proton acceptor sites are available for hydrogen bonding in these compounds. However, intermolecular forces other than hydrogen bonding are present in solid state molecular crystals, and these forces, which influence crystal structure, may also be responsible for the observed spectral trends (Williams, 1981).

Proton nuclear magnetic resonance spectra of all amides were obtained in deuterated dimethyl sulfoxide and were consistent with the expected structures. Correlations of certain nuclear magnetic resonance spectral characteristics with Hammett substituent constants will be the subject of a future communication.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the financial support of E.I. DuPont de Nemours and Company and American Cyanamid Company through fees paid for the testing rights of our new compounds. The University of Arkansas at Little Rock Graduate School is also acknowledged for a teaching assistantship awarded to Jody Z. Caldwell. Special thanks is extended to Dr. E. Kim Fifer at the University of Arkansas for Medical Sciences for the use of a computer software drawing program and his time and instruction.

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PREPARATION OF A SERIES OF SUBSTITUTED N-PHENYL-5-BROMO-2-CHLORO- AND 5-BROMO-6-CHLORONICOTINATES OF POTENTIAL AGRICULTURAL INTEREST

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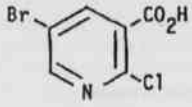
ABSTRACT

Substituted phenyl esters of 5-bromo-2-chloronicotinic acid and 5-bromo-6-chloronicotinic acid were prepared. The acids were first converted to their respective acid chlorides using thionyl chloride, and the acid chlorides were immediately transformed to the esters by treatment with the appropriately substituted phenol in sodium hydroxide solution. A unique chloride displacement of bromide was observed on attempting to convert 5,6-dibromonicotinic acid to its acid chloride.

INTRODUCTION

A recent paper (Setliff, *et al.*) related our continuing interest in the preparation of dihalonicotinic acid derivatives with potential herbicidal, fungicidal, or ascaricidal activity. As an extension of this work, we now describe the preparation of a series of substituted phenyl esters of 5-bromo-2-chloronicotinic acid (I) and 5-bromo-6-chloronicotinic acid (II) (Setliff, 1970). These compounds comprise the first series of esters with suspected activity synthesized by our group.



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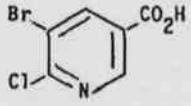
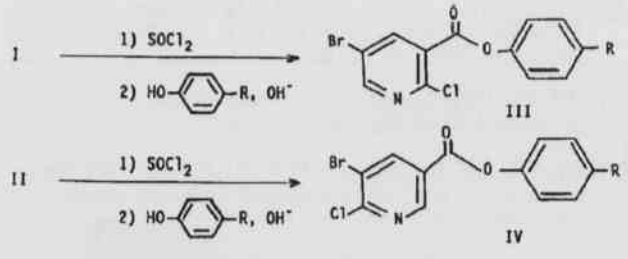


II

MATERIALS AND METHODS

The phenyl 5-bromo-2-chloronicotinates (III) and the phenyl 5-bromo-6-chloronicotinates (IV) were generated by treating the acid chlorides of I and II with the appropriately substituted phenol in basic solution. The acid chlorides were prepared in the normal manner from the acids by use of thionyl chloride. The preparative sequence is summarized in Scheme I below.

Scheme I



Acids I and II were prepared in our laboratory as previously described (Setliff, 1970). The substituted phenols were purchased from Aldrich Chemical company and were technical grade. Melting points were taken on a Mel-Temp apparatus and were uncorrected. Infrared spectra were taken on a Perkin-Elmer 1430 Spectrophotometer equipped with a Model 7300 data station, and samples were prepared as KBr disks. Proton nuclear magnetic resonance spectra were determined on a Varian EM360 instrument with samples dissolved in deuteriochloroform and with tetramethylsilane as the internal standard. Carbon, hydrogen, nitrogen, elemental analyses were performed by Desert Analytics Inc., Tuscon, Arizona.

The following procedure was used to prepare the phenyl esters III and IV. The dihalonicotinic acid I or II (0.500g; 0.002 mol) and thionyl chloride (3 mL) were stirred under gentle reflux for 30 min. During this time the acid completely dissolved. The reaction mixture was cooled to room temperature, and the excess thionyl chloride was removed under reduced pressure on a rotary evaporator (oil bath 50°C). The residual viscous oil (the acid chloride) was used to prepare the ester without further purification. The appropriate substituted phenol (0.015 mol) was dissolved in 5 mL of 0.1 M sodium hydroxide, and the resulting solution was added to the acid chloride. The mixture was stirred vigorously at room temperature for one hour, and then a mixture of ice (5 g) and water (20 mL) was added while stirring was continued. In most cases the ester precipitated. In some cases precipitation was induced by the addition of 10-15mL of cold ethanol to the ice water mixture. The crude ester was collected by vacuum filtration and washed with cold water, followed by ice cold ethanol, and then recrystallized from a small volume of ethanol. Melting points and yields (overall from the acids) are listed in Tables 1 and 2.

Table 1. Experimental, Infrared, and Elemental Analysis Data for the Substituted Phenyl 5-Bromo-2-chloronicotinates (III)

R	% Yld.	MP °C	IR, ν, cm⁻¹		Elemental Analysis Calc'd % (Found %)		
			C=O	C-O-Ar	C	H	N
a. H	61	91	1748	1257	46.08(46.38)	2.24(2.26)	4.48(4.41)
b. Cl	43	103	1752	1279	41.49(41.49)	1.72(1.66)	4.03(3.88)
c. Br	51	120	1734	1282	36.78(36.50)	1.53(1.45)	3.57(3.53)
d. OCH_3	40	73	1733	1262	45.41(45.48)	2.91(2.60)	4.07(4.01)
e. NO_2	42	216	1749	1275	40.28(40.59)	1.67(1.47)	7.83(7.62)

Table 2. Experimental, Infrared, and Elemental Analysis Data for the Substituted Phenyl 5-Bromo-6-chloronicotinates (IV)

R	% Yld.	MP °C	IR, ν, cm⁻¹		Elemental Analysis Calc'd % (Found %)		
			C=O	C-O-Ar	C	H	N
a. H	45	123	1738	1283	46.08(46.19)	2.24(2.09)	4.48(4.39)
b. Cl	43	116	1741	1298	41.49(41.26)	1.72(1.69)	4.03(3.90)
c. Br	45	124	1743	1297	36.78(36.66)	1.53(1.49)	3.57(3.51)
d. OCH_3	55	151	1735	1284	45.41(45.51)	2.91(2.71)	4.07(4.16)
e. NO_2	40	166	1731	1298	40.28(40.36)	1.67(1.49)	7.83(7.66)

RESULTS AND DISCUSSION

Five Substituted phenyl esters were prepared from each of the acids I and II. As noted in Tables 1 and 2, overall product yields from the acids are marginally adequate. Longer reaction times and or heating showed no improvement, and in some cases heating only diminished the yields due to saponification of the esters.

A comparison of the melting points of the isomerically substituted esters reveals that the 5,6-dihaloesters (Table 2) tend to melt higher than their 2,5-dihalo analogs (Table 1) with the exception of the nitro series. In this series the 4-nitrophenyl 5-bromo-2-chloronicotinate (IIIe) melts 50° higher than the corresponding 4-nitrophenyl 5-bromo-6-chloronicotinate (IVe), suggesting a very efficient type of intermolecular association in the crystalline state of the former. These nitro compounds are strong candidates for single crystal X-ray analysis.

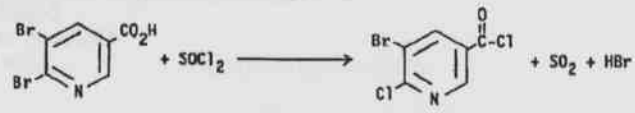
Elemental analysis of all compounds were very satisfactory with percentages falling within acceptable limits of the calculated values. Examination of the infrared spectra revealed the expected absorption bands for both the carbonyl group and carbon to oxygen single bond of the ester functionality. These absorption frequencies are summarized in Tables 1 and 2.

Proton nmr spectra (in $CDCl_3$) were consistent with expected structures. The aromatic pyridine protons appeared downfield from the benzene aromatic protons, and were clearly separated. An interesting comparison is drawn from the spectra of the isomeric methoxy esters III (R = OCH_3) and IV (R = OCH_3), as summarized in Table 3. Most noteworthy is the change in chemical shift of the proton adjacent to the ring nitrogens (H_2 or H_6) in the pyridine ring. This proton becomes more deshielded in compound IVd, when it is *ortho* to the ester carbonyl than in compound IIId, when it is *para* to the ester carbonyl. This is reflected in a downfield shift from 8.70 ppm δ in IIId to 9.35 ppm δ in IVd. Proton H_4 is unaffected by the interchange of chlorine at H_2, H_6, and its chemical shift remains constant at 8.90 ppm δ. The comparisons in Table 3 are typical of all isomeric sets of III and IV esters.

Table 3. A Comparison of the Proton NMR Spectra of the Methoxy Esters IIId and IVd

Cpd.	Pyridine Protons		Benzene Protons		Methoxy Protons
	H_4	H_2 or H_6	H_2	H_3	O-CH_3
IIId	δ 8.90 ppm	δ 8.70 ppm	δ 7.45 ppm	δ 7.10 ppm	δ 3.90 ppm
	d (J=2 Hz)	d (J=2 Hz)	d (J=8 Hz)	d (J=8 Hz)	s
IVd	δ 8.90 ppm	δ 9.35 ppm	δ 7.45 ppm	δ 7.10 ppm	δ 3.90 ppm
	d (J=2 Hz)	d (J=2 Hz)	d (J=8 Hz)	d (J=8 Hz)	s

It was our original intent to also synthesize the analogous esters of 2,5-dibromonicotinic acid and 5,6-dibromonicotinic acid by an identical procedure. When 5,6-dibromonicotinic acid was refluxed with thionyl chloride, the thionyl chloride removed, and the residual acid chloride treated with a basic solution of phenol, there resulted the 5-bromo-6-chloro phenyl ester rather than the expected 5,6-dibromo phenyl ester. We conclude that during the conversion of the acid to the acid chloride there was concurrent displacement of bromine in the 6- position by chlorine as shown below:



This halogen exchange was presumably acid catalyzed by the HCl generated during the reaction. Acid catalyzed displacement of bromine in the 2 or 6 position of pyridine systems has been well documented (Mertel, 1961). That such HCl-catalyzed displacement could have occurred was supported by the fact we observed (by separate experiment) that refluxing 5,6-dibromonicotinic acid in methyl ethyl ketone for 30 minutes with a catalytic amount of 2.5% HCl (aq) caused rapid production of 5-bromo-6-chloronicotinic acid (Caldwell, 1990). The boiling points of methyl ethyl ketone and thionyl chloride are both 78°C, thus identical thermal conditions and reaction times (30 min.) were achieved. Investigation of other plausible mechanistic pathways of the halogen exchange will be carried out at a later date.

In the 2,5-dibromonicotinic acid case, it appears that some displacement of bromine in the 2- position occurs, but not 100%. Treatment of this acid with thionyl chloride, followed by aniline results in a mixture of a dibromo and a bromochloro anilide (Caldwell, 1990). This suggests that the steric effect of the carbonyl group *ortho* to the bromine retards displacement of bromide.

ACKNOWLEDGMENT

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INSTRUMENTATION FOR A POSTURAL SWAY PLATFORM

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ABSTRACT

A postural sway platform has been developed for studies involving elderly fallers. It will be used to assist in determining reasons some elderly people are prone to falling and others are not. Results of these postural sway tests will be combined with other tests on both fallers and nonfallers to determine specific reasons for falling. A simple Z-axis platform has been developed that utilizes a unique hanger system and three strain gage transducers. The output of these transducers is input to an analog-to-digital conversion board in a personal computer. Software has been written to take data from the platform and display it graphically on the computer screen. This display includes real-time information on the center of gravity of the patient, as well as his/her weight. Arithmetic means are then calculated on the accumulated sway pattern data. These results and the results of other tests on patients can then be used to determine if a patient may be prone to falling.

INTRODUCTION

Falling results in injury that threatens the health of the elderly (65+) population and is the leading cause of accidental death (Rubenstein *et al*, 1988; Rodstein, 1985). One third to one half of the elderly have one or more falls per year. Injuries from falling may result in mortality in up to 50 percent (Cummings *et al.*, 1985; Wild, 1980). The most common serious injury is hip fracture (Ochs, 1988). Recent reviews (Rubenstein *et al.*, 1988; Nickens, 1985; Christiansen, 1987) suggest three main physiological factors as the major cause of falls. These are: reaction time, nerve conduction speed, and postural sway. Nerve conduction velocity slows with advancing age (Dorfman, 1979). Reaction time also increases with age, due to slower processing, movement and conduction times (Era, 1986; Gottsdanker, 1982). Balance is defined as maintenance of the body's center of gravity close to the center of its base support. The inability to maintain this or adjust it, can result in a fall. Increased postural sway, suggesting inaccurate balance control, has been shown in elderly subjects (Lichtenstein, 1988; Murray, 1975) and elderly fallers (Fernie *et al.*, 1982).

A research project designed to test reaction me, nerve conduction and postural sway has been approved. It will be conducted at the Veterans Administration Hospital in Little Rock, using elderly patients. This paper deals with the design and development of the postural sway platform used in this project. Included is the software to acquire, display and save the data. While postural sway may play an important role in falling, this test must be used in conjunction with other tests to be considered conclusive.

EXPERIMENTAL DESIGN

The Z-axis platform is constructed of 6061-T6 aluminum and is designed to be rugged, very stable and inexpensive. It consists of a main circular platform and three bases (Fig. 1). The bases lie on the floor and the three arms of the platform each fit into a base. Proper alignment with the platform is obtained by using an adjustable stabilizer to connect the bases. The bases are a unique design (Fig. 2), utilizing a hanger system, so when assembled the platform suspends from the bases. Attached to the end of each of the arms on the main platform is a load cell (Fig. 3). The load cells attach to the bases and they measure the forces on the platform. The hangers minimize the transverse forces resulting from temperature changes and uneven floors, providing a stable system and more accurate data.

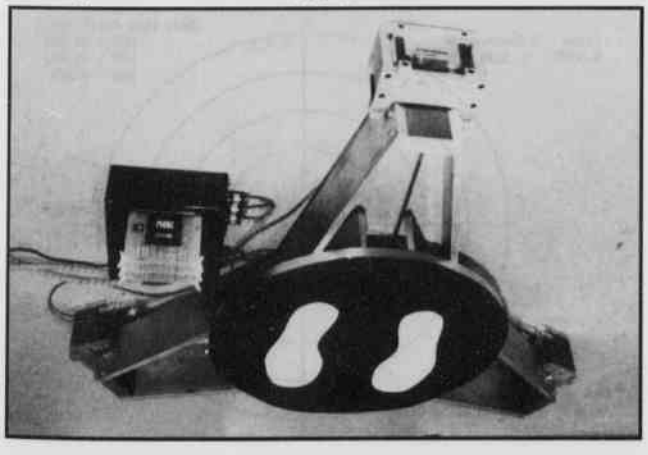

Figure 1. Sway platform system.

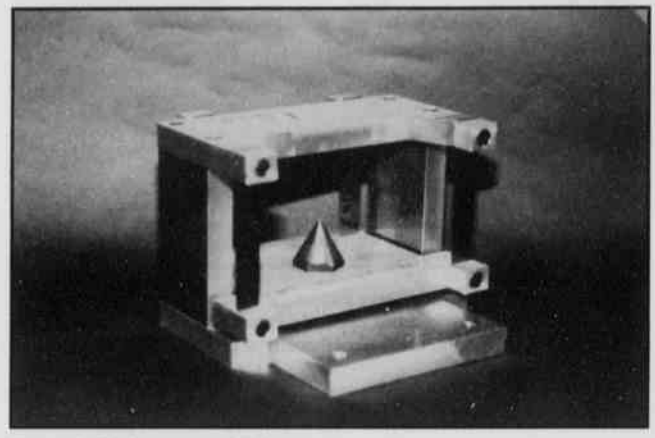

Figure 2. Platform base utilizing hanger system.

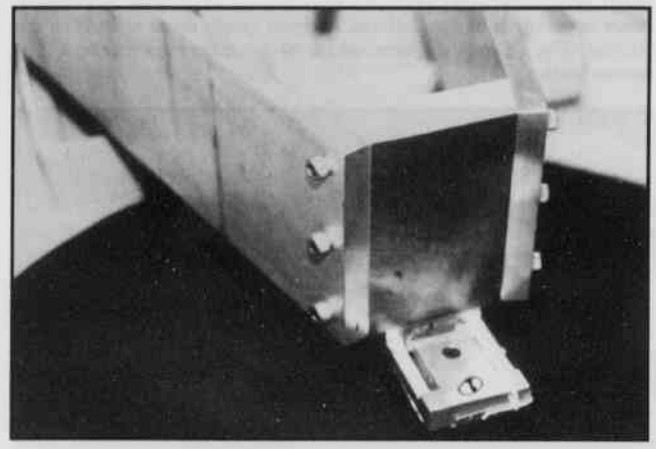

Figure 3. Load cell attached to the end of the platform arm.

Instrumentation for a Postural Sway Platform

The load cells are constructed from 2024-T86 aluminum with a yield strength of 71,000 psi. They are designed to flex as a sigmoid and utilize four strain gages to measure the deflection (Fig. 4). Strain gages from each load cell are set up in a bridge configuration. The strain gages, from Measurements Group, are 350 ohms with a gage factor of 2.15. Excitation and amplification for the strain gage bridges is provided by using Analog Devices 2B31J instrumentation amplifiers. The output of these amplifiers is then input to an ADACMF-5500 12-bit analog-to-digital converter board installed in a Zenith 386 personal computer. Software has been written to acquire and graphically display a patients' sway pattern, and to store it in a data file.

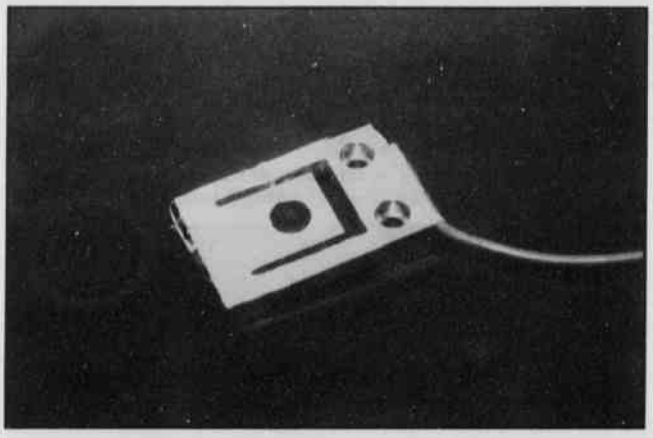

Figure 4. Strain gage load cell, with cup in center.

To determine a subjects' sway pattern, they stand on the platform and the load cells measure the force applied to each of the three bases. From the distribution of weight, the subjects' center of gravity can be calculated.

RESULTS AND DISCUSSION

Problems with many of the postural sway platforms being used today are they are large, fairly immobile and expensive. The platform that has been designed for this study is small, rugged, portable and inexpensive. This sway platform measures a person's center of gravity by using a platform that is supported by three load cells. Each load cell measures the weight on that arm of the platform, which enables us to measure where the center of gravity is on the platform. Asubject simply needs to stand on the platform (Fig. 5), and the system calculates the center of gravity on a continuous basis.

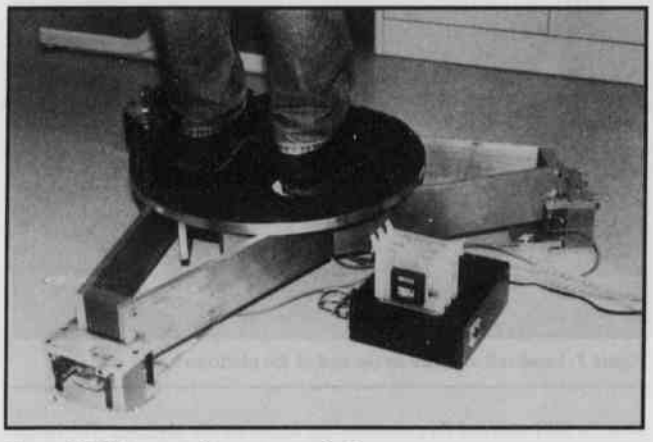

Figure 5. Subject standing on sway platform.

After building the load cells, calibration showed each to give approximately 2 millivolts/volt output for a full scale load of 150 pounds. Designed to withstand a 100 percent overload, the load cells can support 300 pounds on each, before the yield point of the metal is reached. The design of the platform is such that a 300 pound subject could stand anywhere on the platform and not produce a load greater than 200 pounds on a transducer.

The construction of the bases utilizing a hanger system assures that the platform is not affected by uneven surfaces, temperature factors, or other detrimental factors. Each load cell has a cup that fits on a cone in its base hanger (Fig. 4). This cup and cone design allows placement on somewhat uneven surfaces. Each of the hangers is suspended from its base by four metal straps, this allows movement perpendicular to the tangent of the platform. This insures there are no lateral forces applied to the load cells.

Software was written to acquire the sway pattern data, display it graphically and to store it in a data file. First the program has an automatic tare, to account for the weight of the platform itself. The subject then stands on the platform and the system takes 1000 data points over a period of 50 seconds and displays it on the computer screen (Fig. 6). Means are

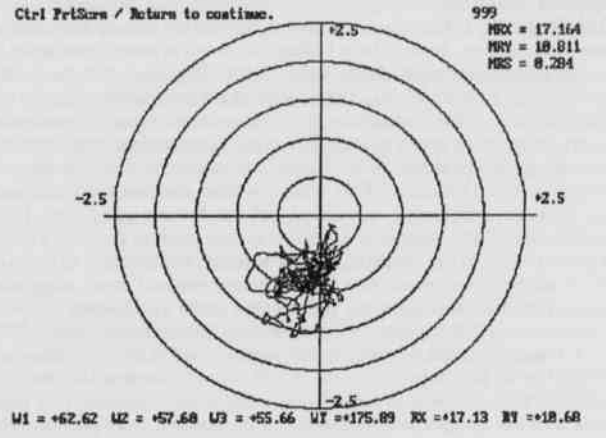

Figure 6. Sway pattern data.

calculated from the data, and the center of the sway pattern is found. Also computed is the mean radius. The data are then centered on the screen, the mean radius drawn and a least-squares line is drawn through the data (Fig. 7). Included on the screen is the percentage of time the subject spent in

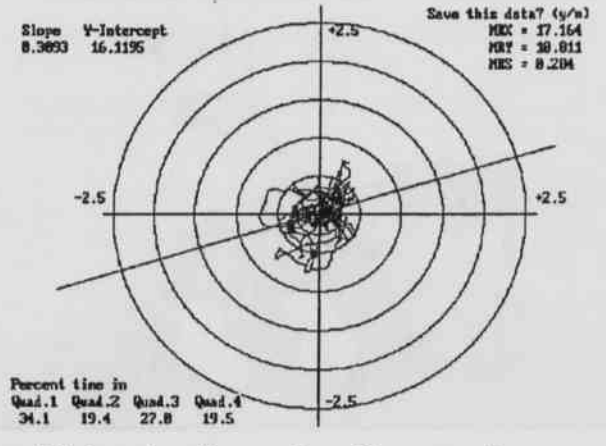

Figure 7. Redrawn data with mean radius and least-squares line.

each quadrant of the display, the subjects weight, and the calculated means. These factors and the area of the sway pattern can be used to determine if a subject has an excessive sway pattern. A prompt is then given to the user to ask whether he wants to print the data and whether to save the data in a file. The software is written in Microsoft C 6.0.

CONCLUSIONS

Compared to postural sway platforms of the past, the design and implementation of this postural sway system is an improvement. It is rugged, portable and inexpensive. The platform should prove to be a useful tool in determining the amount of postural sway a subject exhibits. This test, with others, will be used in the falling study to determine if a subject may be prone to falling.

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FIVE-YEAR STUDY OF *GEOCARPON MINIMUM* AT WARREN PRAIRIE NATURAL AREA BRADLEY COUNTY, ARKANSAS

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ABSTRACT

Geocarpon minimum, listed by the U.S. Fish & Wildlife Service as threatened, was monitored at Warren Prairie Natural Area, Bradley County, Arkansas, 1986-90. Selected environmental variables were compared with *Geocarpon* productivity plot by plot. Principal components (PC) analysis generated two eigenvectors that jointly accounted for 30% of the variation among plots. PC-Idescribes an exposure gradient; high-productivity plots had less litter and grass cover, more cryptogamic lip, and more iron nodules lying on the surface than most other plots. PC-II was more useful for separating highly productive plots from all other plots; the highly productive plots lay in close proximity to slicks and remote from low spots where shallow water stands after a rain. *Geocarpon* productivity at Warren Prairie Natural Area peaked in 1987 and has declined steeply and steadily in the following years. Recommendations for further study are offered.

INTRODUCTION

This paper reports results of monitoring *Geocarpon minimum* 1986-90 at Warren Prairie Natural Area, Bradley County, Arkansas. *Geocarpon minimum* (Caryophyllaceae) has been on the U.S. Fish &Wildlife Service's list of threatened species since 16 July, 1987. Warren Prairie Natural Area (302 acres) has been under joint protection by the Arkansas Natural Heritage Commission (301 acres) and the Nature Conservancy (1 acre plus an easement on the remainder) since 11 January 1983. In 1990, the Commission acquired an adjacent tract of 275 acres in Drew County, making a new total of 577 acres. The Natural Heritage Commission is an agency of the Department of Arkansas Heritage.

Study design and data collection in the first year of the study were reported in Bridges (1986). Data collection in the second year and plot-by-plot comparison of 1986 and 1987 data were presented with discussion by Shepherd (1987). Results from 1988 were presented by Shepherd (1988). The present report describes monitoring that was conducted in the spring seasons of 1989 and 1990, draws final conclusions concerning microhabitat factors that make possible predictions concerning the occurrence and abundance of *Geocarpon*, and considers the overall trend of *Geocarpon* abundance on the study site throughout the period of investigation.

GEOCARPON MONITORING IN 1989 AND 1990

Data from 1989 and 1990 were collected according to revised procedures as described in Shepherd (1988), except that less information was recorded from each plot in 1990 and in the second sampling of 1989. The same selected plots run in 1988 were sampled in 1989 on 13 and 14 March and again on 24 and 25 March. (Seven additional plots were run and included in the sample as a precaution against loss of plots to disturbance; these were selected randomly in accordance with the same procedures followed in 1988.) Preliminary sampling was conducted on 6 March 1990, to assess the phenologic status of the *Geocarpon* population, and all 57 selected plots were run on 18 March.

The only information recorded on 24-25 March 1989 was the number of *Geocarpon* plants per plot, the percentage of plants exceeding 1 cm in height, and the total vascular plant cover. Plot information recorded 18 March 1990 was limited to the number of *Geocarpon* plants, percent lichen cover, and percent vascular plant cover.

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RELATIONSHIP BETWEEN *GEOCARPON* PRODUCTIVITY AND SELECTED ENVIRONMENTAL VARIABLES

1988 Data were analyzed as follows: The number of *Geocarpon* plants per plot was used as a measurement of *Geocarpon* productivity; plots were classified as non-productive (0 plants), slightly productive (1-30 plants), moderately productive (30-50 plants), or highly productive (>50 plants). Principal components analysis (Morrison, 1976; Gauch, 1982) was used to characterize study plots with respect to microhabitat features. (See Table 1 for a description of microhabitat variables included in our analysis. "Slicks" are patches of whitish, almost bare soil with very high concentrations of sodium salts. The "cryptogamic lip" is a shallow ring of mixed soil particles and fibrous material that tends to surround each slick. See Pittman [1988] for further explanation.)

Table 1. Eigenvectors of the first two principal components.

*VARIABLES	PC - I	PC - II
L	-0.485	-0.070
B	0.112	-0.077
FE	0.260	0.239
LIP	0.374	0.326
LCH	-0.027	0.176
NOS	0.245	-0.335
MOSS	-0.003	-0.244
LWORT	0.098	0.154
AB	-0.161	-0.198
HA	0.232	-0.286
HD	-0.227	-0.065
PH	0.045	0.417
R	0.297	-0.375
SK	-0.190	0.007
TP	-0.066	0.399
UG	-0.456	-0.001

*L = litter, B = bare ground, FE = iron nodules lying on soil surface, LIP = cryptogamic lip (defined in Pittman [1988]), LCH = unidentified lichens, NOS = *Nostoc* spp., MOSS = unidentified mosses, LWORT = unidentified liverworts, AB = *Ambrosia bidentata*, HA = *Hedyotis australis*, HD = *Hypericum drummondii*, PH = *Plantago hybrida*, R = *Ranunculus* spp., SK = *Scirpus koilolepis*, TP = *Talinum parviflorum*, UG = unidentified grasses.

The first principal component (PC-I) accounted for 17% of the variation among plots and described a gradient of increasing iron nodules and cryptogamic lip and decreasing litter and unidentified grasses. Therefore, PC-I describes an exposure gradient; in high-productivity plots there was less litter and grass cover, more cryptogamic lip, and more iron nodules lying on the surface.

The second principal component (PC-II) accounted for an additional 13% of the environmental variation and described a gradient of increasing cryptogamic lip, *Plantago hybrida*, and *Talinum parviflorum;* and decreasing *Nostoc* and *Ranunculus* sp. In habitat terms high values of PC-II indicate close proximity to slicks and remoteness from low spots where shallow water stands after a rain. (The lip develops near slicks; *Plantago hybrida* and *Talinum parviflorum* tend to grow close to slicks; *Nostoc* grows in standing water; and *Ranunculus* sp. tends to grow in or near standing water.) Highly productive *Geocarpon* plots were characterized by medium to high values of PC-I and high values of PC-II, i.e. highly productive plots were located near slicks, in plots with relatively well developed cryptogamic lip and high iron content. Non-productive, slightly productive, and moderately productive plots were generally indistinguishable with respect to PC-I and PC-II axes (Fig. 1).

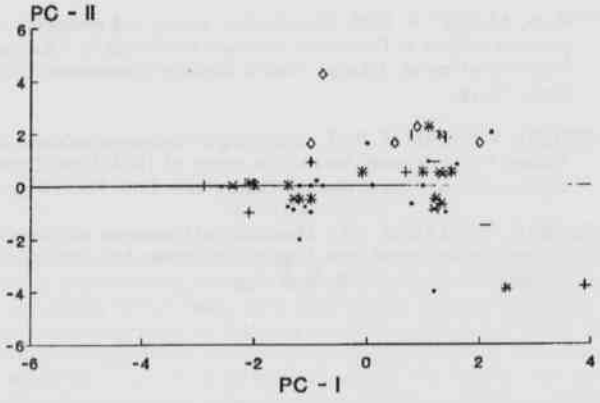

Figure 1. Ordination of study plots with respect to the first two principal components.

■ Plots with no *Geocarpon* plants
* Plots with 1 - 30 *Geocarpon* plants
\+ Plots with 31 - 50 *Geocarpon* plants
◇ Plots with more than 50 *Geocarpon* plants

Jointly, PC-I and PC-II accounted for only 30% of the variation among plots. Thus there may be other, more important variables that were not measured or included in the study.

In summary, our PCA yielded a partial description of *Geocarpon* microhabitat that is consistent with Pittman's (1988) qualitative description. In general, *Geocarpon* grows in well drained spots close to slicks, and its closest associate is *Plantago hybrida*. However, our analysis failed to enable us to discriminate clearly among groups of plots on the basis of productivity. Alarger sample size, with a better balance between the highly productive plots and the less productive ones, would be valuable for evaluating further the relationship between geocarpon productivity and microhabitat variables.

We believe multivariate analytic techniques show promise for guiding habitat-management for rare plants and possibly also for guiding searches for populations of rare plants. As the habitat of *Geocarpon* is extremely patchy, even within the treeless parts of Warren Prairie Natural Area, so that distances of even a few centimeters often mark the difference between good habitat and unsuitable habitat, we want to emphasize that using the most appropriate scale for habitat analysis is absolutely essential to any hope of obtaining meaningful results. In the present case, where a very small scale is required, higher correlations might have been obtainable if 25cm^2 cells rather than 0.1m^2 or 0.04m^2 plots had been compared.

TREND OF PRODUCTIVITY IN *GEOCARPON* 1986-90

Figure 2 charts the productivity of *Geocarpon* in the reduced sample of 57 selected plots 1986-90. The figure used for 1990 should be viewed with special caution.

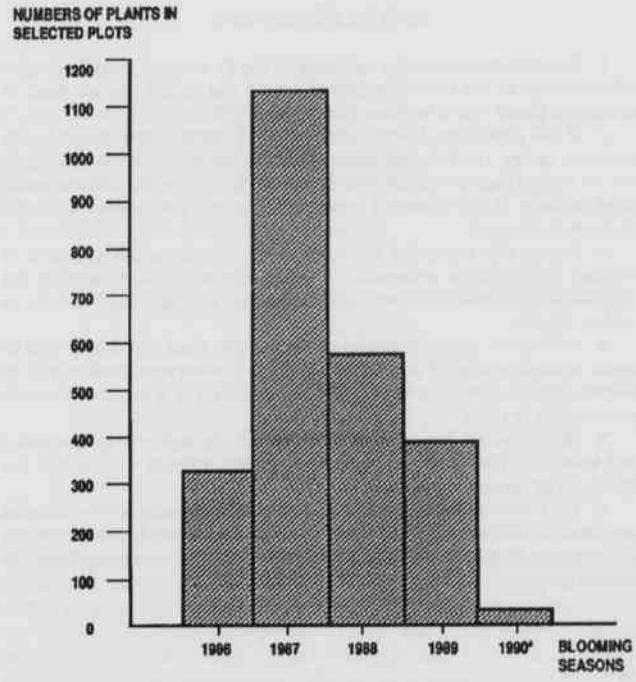

Figure 2. *Geocarpon* productivity in selected plots 1986-1990.
*1990 count conducted after the peak of bloom had passed (see text).

We believe we were fairly successful in timing the annual survey of the geocarpon population to coincide with its peak of bloom 1987-89. However, we know we missed the peak in 1990. On 6 March, 1990, Steinauer made a preliminary survey of 33 four-row plots from the reduced sample. The 33 plots selected for the 6 March, 1990, preliminary survey were all the plots in which *Geocarpon* plants were found in the 1989 survey; and, as demonstrated by Shepherd (1987), year-to-year consistency is strong. On 6 March, 1990, Steinauer counted a total of 39 geocarpon plants in the 33 plots. When all 57 plots in the reduced sample were surveyed 18 March, 1990, only 33 plants were found. Thus it is evident that the number charted (33) is lower than the one that would have been obtained had it been possible to survey the entire set of 57 plots earlier in the month. However, the numerical difference between the totals from the two dates in March, 1990 is small. (Excessive rain, which kept the soil soft and muddy, made it imprudent to attempt a survey 7-17 March, 1990.)

The productivity curve charted here is consistent with the hypothesis that *Geocarpon minimum* is dependent on disturbance in the surface of the soil but peaks in abundance 4 or 5 years after the disturbance takes place, provided there is no further disturbance. (An alternative hypothesis would be that the weather was unfavorable for *Geocarpon* in 1989 and 1990, though frequent rains during the blooming season created an impression of favorableness. We know nothing about possible effects of summer, fall, and early winter weather on *Geocarpon* productivity in March and April. Still another possibility is that the 1990 peak of blooming occurred in February or even January.)

A wheeled vehicle's disturbance of surface soil in the middle of *Geocarpon* transect D on 7 November 1987 created a ready-made experi-

ment for testing the hypothesis that *Geocarpon* responds positively, though belatedly, to disturbance. If the high population of *Geocarpon* in 1987 represented a positive response to disturbance early in 1983, a similar response in plots D-24, D-28, and D-29 may be expected in 1991 or 1992. To prevent further disturbance from clouding the picture, Transect D was surrounded with a well flagged barbed-wire fence in 1989.

RECOMMENDATIONS

1. It is recommended that sampling of the 57 selected plots be continued annually in the late winter/spring until and unless the numbers of geocarpon plants found in those plots exceed 300.
2. If this population level is not reached in another year of apparently adequate spring rainfall, experimental disturbance should be created at one or more fence-protected locations and these plots should be monitored annually in the blooming season for at least 5 years even if no other plots are monitored.
3. Especially since the evidence is equivocal on the question of whether geocarpon is a biennial, a winter annual, or both, monitoring visits should be made in November, December, January, and February as well as March.
4. Studies on the germination of *Geocarpon* seed could help lead to better understanding of annual variation in *Geocarpon* productivity at Warren Prairie. (See Shepherd [1987] for specifics of a proposal to study germination *in situ*.)
5. Have Warren Prairie studied thoroughly by both a geologist and a soil scientist. The latter, in particular, should attempt to describe the dynamics of the surface disturbance cycle.
6. For better understanding of *Geocarpon*'s response to microhabitat variables, establish additional study plots in highly productive locations and conduct further multivariate analysis. Consider using smaller plots for this purpose.

ACKNOWLEDGMENTS

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DISTRIBUTION, SCUTELLATION, AND REPRODUCTION IN THE QUEEN SNAKE, *REGINA SEPTEMVITTATA* (SERPENTES: COLUBRIDAE), FROM ARKANSAS

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ABSTRACT

The queen snake, *Regina septemvittata*, has a disjunct portion of its distribution in Arkansas. This rare, crayfish-eating species is best known from only a few isolated populations from several major streams that flow out of the Boston Mountains of the Ozark Plateau. A field study of this species was conducted during the summer of 1990, and only 4 specimens were documented. Gravid females were collected in July; sperm production was also noted in July. Parturition presumably takes place in August or early September. This species may qualify as threatened or endangered in Arkansas.

INTRODUCTION

The queen snake, *Regina septemvittata*, is a medium-sized, semi-aquatic, crayfish-eating, natricine snake and has an extensive distribution in the eastern United States and a much smaller disjunct distribution in the Interior Highlands of Arkansas and Missouri (Conant, 1975). The trans-Mississippi River populations are disjunct from the westernmost extent of the main body of the species' range by over 400 km. The queen snake is best known in Arkansas from only a few isolated populations from several major streams that flow out of the Boston Mountains of the Ozark Plateau. Although the Mulberry River of west-central Arkansas (Franklin and Johnson counties) historically contains documented scattered populations (Dowling, 1957; Conant, 1960; Weatherby, 1974; Trauth, 1988), many other streams have not been investigated as thoroughly as this one. The first specimens of *R. septemvittata* collected in Arkansas were taken from the Hot Springs area (Garland County) between 1894 and 1896 (Hurter and Strecker, 1909). After conducting an exhaustive search for voucher specimens, Conant (1960) could find records for only seven specimens from Arkansas and three from Missouri. Recently, Johnson (1987) mentioned that no additional specimens of queen snakes have been reported from Missouri since 1927. Plummer (1980) reported two significant new county records for Arkansas; these localities (Cadron Creek – Faulkner County; Salado Creek – Independence County) represent populations that reside outside of the published range (Conant, 1975).

Dowling (1956) discussed a possible correlation between the presence of endemic relictual populations of amphibians and reptiles in the Interior Highlands of Arkansas and the geologic and paleoclimatic history of the region. Surprisingly, Dowling (1956) failed to include *R. septemvittata* as occurring in either the Arkansas River Valley or the Ouachita Mountains. He suggested that the disjunct distributions present in many of the species' ranges occurred following herpetofaunal immigrations into this region during four separate climatic episodes during the late Pleistocene or early Holocene (Smith, 1957; Auffenberg and Milstead, 1965; Cole, 1971). A striking parallelism exists between the two disjunct segment of the range of *R. septemvittata* and its principal food source, crayfish of the genus *Cambarus*, in Arkansas (Conant, 1960; Branson and Baker, 1974).

Literature dealing with the natural history of the queen snake is scant; the only intensive ecological study was conducted by Branson and Baker (1974) in Kentucky. Recent studies on *R. septemvittata* include the topics of skin permeability (Stokes and Dunson, 1982), scale surface microstructure (Price, 1983), flight responses (Layne and Ford, 1984), foraging habits (Godley *et al.*, 1984), and coccidian parasites (Upton *et al.*, 1991). Weatherby (1974) conducted a study on the population genetics of *R. septemvittata* throughout its range and utilized 21 specimens (mostly neonates) from Johnson County; other than checklists (Vance, 1985), general accounts in books (Mount, 1975; Ernst and Barbour, 1989), and Conant's review (1960), Weatherby's work represents the only major document on any aspect of the biology of the queen snake west of the Mississippi River. Reagan (1974) and Smith *et al.* (1984) pointed out the need for a critical assessment of the status of *R. septemvittata* in Arkansas.

The present study was undertaken to identify new populations of *R. septemvittata* in Arkansas and to verify the existence of populations from localities of previous state records. In addition, museum specimens were examined to summarize data on size and scutellation and dissected to reveal their reproductive condition. Information presented, herein, will add to a database on this species in Arkansas.

MATERIALS AND METHODS

Field work was conducted May through September, 1990. Thirty-seven localities in 11 counties were visited (Table 1); five of these were searched more than once. The primary collecting method was turning over large rocks within streams or along their edges (Branson and Baker, 1974). At each site, a distance of from 0.2-0.8 km above and below the entrance point was investigated. Snakes were killed by an intraperitoneal injection of sodium pentobarbitol. The snout-vent length (SVL) and tail length (TL) were measured following fixation in 10% formalin and preservation in 70% ethanol. Testes were removed from three males (includes museum specimens) and prepared for light microscopy using standard histological methods (Humason, 1979). In four females, vitellogenic ovarian follicles, oviductal eggs, and/or developing embryos were counted and measured. All snakes collected during this study were deposited in the Arkansas State Museum of Zoology.

Table 1. Snake survey data from 37 collection sites from major creeks or river systems within the Interior Highlands of Arkansas. Data were gathered during the spring and summer of 1990. Snake species include: *Agkistrodon piscivorus leucostoma* (APL), *Nerodia erythrogaster flavigaster* (NEF), *N. sipedon pleuralis* (NSP), and *Regina septemvittata* (RS). The number of snakes collected is followed by the number observed (in parentheses). Asterisk denotes site of a literature record.

County and General Locality	Township, Range, Section	Snake Species
Crawford		
Mulberry River and Interstate 40	T10N, R29W, Sec 24	2 NSP; 1 RS
Mulberry River and St. Hwy 215	T10N, R29W, Sec 14	2 NSP (4)
Jone's Fork (Frog Bayou)	T12N, R29W, Sec 8	2 NSP
Frog Bayou and NFR 1000)	T12N, R29W, Sec 10	-
Frog Bayou and St. Hwy 282)	T11N, R30W, Sec 21	3 NSP
Lee Creek and U.S. Hwy 59	T11N, R32W, Sec 10	2 NSP
Faulkner		
*Cadron Creek and U.S. Hwy 65	T8N, R13W, Sec 29	-
Batesville Creek and U.S. Hwy 65	T8N, R13W, Sec 8	-
Franklin		
Mountain Creek	T12N, R26W, Sec 19	1 NSP
*Mulberry River and St. Hwy 23	T12N, R27W, Sec 35	1 APL; 2 NSP
Mulberry River	T12N, R27W, Sec 35	-
Hurricane Creek	T11N, R28W, Sec 10	-
Mulberry River and Interstate 40	T10N, R29W, Sec 24	1 NSP; 1 RS
Garland		
*Hot Springs Creek	T3S, R19W (Fontana Rd., Hot Springs)	4 NSP
Hot Spring		
Blakely Creek and St. Hwy 84	T4S, R18W, Sec 35	1 NSP (4)
Independence		
*Salado Creek	T11N, R7W, Sec 2	1 APL; 9 NSP (11)
Salado Creek	T12N, R7W, Sec 35	3 APL
Salado Creek and U.S. Hwy 167	T11N, R6W, Sec 2	-
Johnson		
Big Piney Creek and St. Hwy 123	T12N, R12W, Sec 20	1 NSP
Little Piney Creek and St. Hwy 123	T11N, R22W, Sec 26	-
Horsehead Creek	T11N, R25W, Sec 24	-
Mulberry River	T12N, R23W, Sec 16	-
Mulberry River	T12N, R24W, Sec 21	-
*Mulberry River and Co. Hwy 103	T12N, R25W, Sec 24	2 NEF; 3 NSP (5); 2 RS
Mulberry River	T12N, R24W, Sec 21	1 NSP
Madison		
Kings River and St. Hwy 74	T16N, R24W, Sec 28	1 NSP
Newton		
Buffalo River and St. Hwy 21	T15N, R23W, Sec 15	-
Pope		
Illinois Bayou and St. Hwy 164	T10N, R19W, Sec 21	-
Illinois Bayou	T10N, R19W, Sec 32	-
Illinois Bayou and St. Hwy 27	T10N, R19W, Sec 24	NSP (1)
Illinois Bayou and NFR 1000	T12N, R19W, Sec 21	-
Big Piney Creek and St. Hwy 164	T10N, R21W, Sec 24	3 NSP
Van Buren		
Pee Dee Creek	T11N, R13W, Sec 7	-
Weaver Creek	T12N, R13W, Sec 34	-
South Fork, Little Red River and St. Hwy 95	T11N, R15W, Sec 33	1 NSP
South Fork, Little Red River	T11N, R15W, Sec 30	1 APL (2); 1 NSP

RESULTS AND DISCUSSION

DISTRIBUTION

Four *Regina septemvittata* were collected during the present study from three localities in Crawford and Johnson counties (Fig. 1; sites 2, 3, and 5). No queen snakes were observed at any other locality; this includes the historic sites (1, 4, 6, 7, and 8).

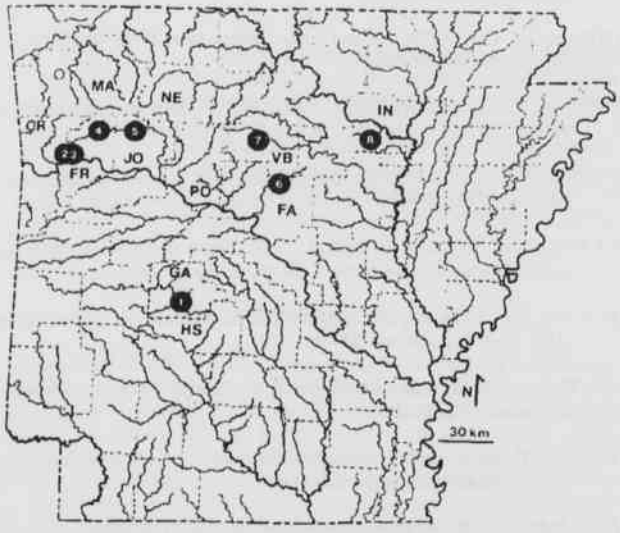

Figure 1. Map of Arkansas showing major drainage systems. Numbered sites representing known localities from voucher specimens or literature records for *Regina septemvittata* are: 1) Hot Springs Creek, 2-5) Mulberry River, 6) Cadron Creek, 7) South Fork, Little Red River, and 8) Salado Creek. Abbreviations for counties are: Crawford (CR), Faulkner (FA), Franklin (FR), Garland (GA), Hot Spring (HS), Independence (IN), Madison (MA), Newton (NE), Pope (PO), and Van Buren (VB). Open circle represents historic site, although no voucher specimen presently exists (Dowling, 1957).

SCUTELLATION AND SIZE

Data on scutellation of Arkansas specimens (n = 7) of *Regina septemvittata* are found in Conant (1960). The following data (mean, range, and no. of specimens) on counts of ventrals and subcaudals by sex (males followed by females) include the specimens analyzed by Conant (1960): ventrals – 152.6, 144-159, 7, 153.4, 151-157, 10; subcaudals – 72.4, 71-74, 5, 67.1, 62-77, 10. These same counts on a single clutch of late-term embryos are: ventrals – 151.2, 147-155, 6, 149.8, 148-152, 4; subcaudals – 73.0, 66-78, 6, 68.0, 57-69, 4. The female of this clutch possessed 152 ventrals and 64 subcaudals. The grand total for all specimens (± 2 SE) are: ventrals – 152.1±1.2, 144-159, 27; subcaudals – 69.7±2.1, 57-78, 25. The mean values for the number of ventrals was greater than values found for *R. septemvittata* in Ohio (Wood and Duellman, 1950), whereas the mean number of subcaudals in the Arkansas specimens was approximately equal to those in Ohio.

The largest Arkansas specimen was a female measuring 528 mm SVL (total length, 658 mm) of seven adults examined; the largest male measured 443 mm SVL (tail broken). As pointed out by Wood and Duellman (1950), females are always the longest specimens regardless as to what part of the range specimens are collected. Newly-born young of *Regina septemvittata* range from 166-225 mm in total length (Wood and Duellman, *op. cit.*). One juvenile, collected 16 September 1972, measured 198 mm SVL and 63 mm TL. A gravid female, collected 23 July 1987, contained embryos (n = 10) that averaged 106.1 mm SVL (range, 103-109) and 35.5 mm TL (33-38).

REPRODUCTION

Clutch and/or litter size in *Regina septemvittata* was summarized by Fitch (1985); northern populations in the eastern United States averaged 16.4 (4-39), whereas southern populations averaged 12.2 (6-19). Clutch size in two Arkansas females (SVL = 380 and 440 mm) exhibiting small yolked ovarian follicles (mean length, 3.5 and 4.4 mm) was 14 and 19, respectively. In two gravid females (SVL = 469 and 528 mm), clutch size was 7 and 10, respectively. Based upon the size of the embryos of the above gravid females, it appears that queen snakes give birth in August or early September. Queen snakes are known to mate in the spring and/or the fall (Branson and Baker, 1974). A histological examination of the left testis of an adult male (SVL = 403 mm) collected 20 July 1990 revealed sperm within the seminiferous tubules (Fig. 2).

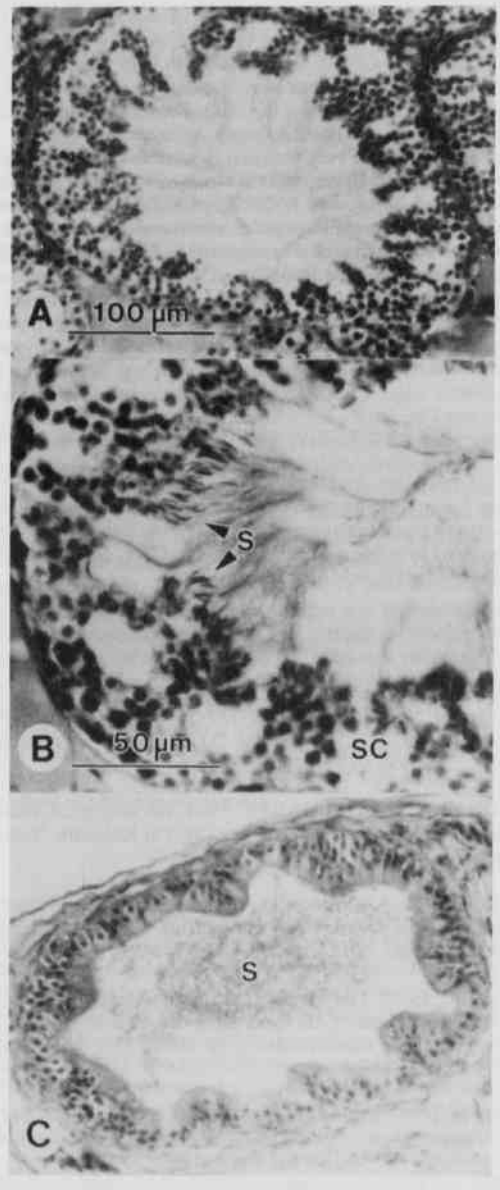

Figure 2. Photomicrographs of seminiferous and epididymal tubules of *Regina septemvittata*. A. Seminiferous tubule in the process of spermiation. B. Magnification of a seminiferous tubule showing the release of sperm (S). C. Epididymal tubule with sperm (S). Magnification the same as in A.

Ernst and Barbour (1989) pointed out that queen snakes prefer clean, unpolluted streams in the eastern United States. They also stated that water pollution and possibly acid rain have reduced crayfish populations in many parts of the range of queen snakes and have eliminated the snake from these areas. During the present study, water pollution was obvious, especially in the Mulberry River. Enrichment of flowing water from cattle pastures, poultry operations, and human occupation along the Mulberry as well as other rivers may be the greatest threat to the survival of queen snakes within the snake's optimal habitats in the Boston Mountains. The present study was unable to establish the existence of any large aggregates or populations of queen snakes, possibly because most of the sites investigated showed heavy use by man. All streams within the Boston Mountains become flowing torrents after heavy spring rains; this is especially common in early spring at the time when queen snakes have not left their hibernation dens. These rain showers may, in effect, temporarily cleanse terrestrial habitats of their sources of enrichment prior to emergence by snakes. By mid-to-late summer, these watersheds receive reduced amounts of rain and become sluggish with respect to the movement of nutrients. Algal blooms were common in several streams during late summer; however, the effect of polluted watersheds on the life history of *R. septemvittata* in Arkansas remains unknown.

Queen snakes may be very common in suitable habitats with abundant crayfish (Branson and Baker, 1974); Wood (1949) collected 125 specimens within 92 m in a stream in Ohio. The rarity of queen snakes in the presence of abundant crayfish populations (as was the case in the present study) may be suggestive of a species nearing extirpation from causes other than diminished food resources. The biology of *R. septemvittata* will require further study before its status can be adequately determined in Arkansas; yet, based upon the present findings (or lack thereof), this species qualifies as a rare species and deserves formal recognition as being threatened or endangered.

ACKNOWLEDGMENT

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A RADIOMETER FOR THE INVESTIGATION OF INFRARED EMISSIONS FROM FLAMES AND ROCKET PLUMES

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ABSTRACT

A prototypical radiometer using standard one inch interference filters and a lead selenide detector was constructed for use in flame and rocket plume studies. This radiometer was designed to employ a 600 Hz chopper and chopper frequency/phase reference circuit for signal processing. Bandpass filters centered for either 2.7 μm or 4.45 μm were placed in the optical path. The passed carbon dioxide or water vapor band energy irradiated the lead selenide detector, resulting in an output voltage. This signal was then fed into a dedicated synchronous detector. The signal was then recorded by a computer system equipped with an analog-to-digital converter board. Infrared emission data was collected from two inch rocket motors and from a special burner based flame.

INTRODUCTION

Since the end of World War II, emissions from hot gases have been of major importance in scientific study. Early interest was in the area of missile guidance. Typically, model systems were used to simulate emissions found in jet exhaust (Plyler, 1948). However, in more recent times, investigations have been undertaken on infrared emissions from rocket plumes (Ambruso and Slack, 1983). The spectral area of most interest was the 1 to 5 μm region. This area is very important because of the large water band centered at 2.7 μm and the intense carbon dioxide band at 4.4 μm. Fig. 1 shows the spectra for a hydrogen/air and an acetylene/air flame, demonstrating that the 4.4 μm band is absent in the H_2/Air flame and that it is intense in the C_2H_2/Air flame.

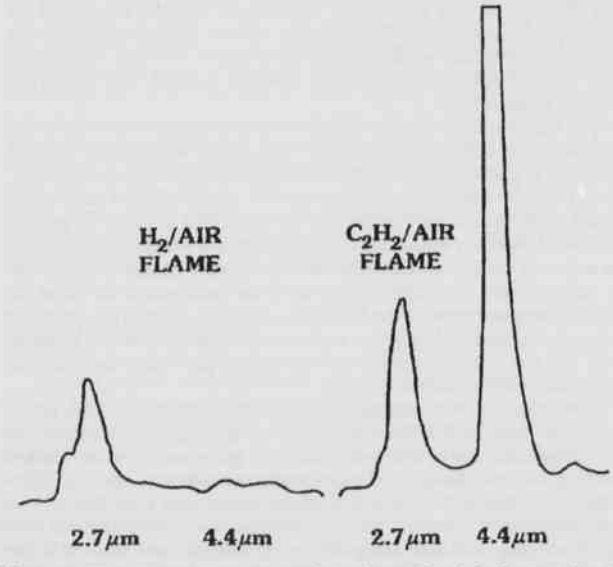

Figure 1. IR spectra for hydrogen/air and acetylene/air flames showing the 2.7 and 4.4 gaseous emission bands.

Existing systems which can be used for this application require very sophisticated equipment, including Fourier Transform Infrared (FTIR) instruments and imaging systems. Albrechcinski and Wurster (1979) reported rapid scanning instrumentation for both spatial and spectral measurements in rocket plumes. Spatial scanners were set atop a chamber, and were used to map the infrared region from 1 to 5.5 μm. The spatial scanners used indium antimonide detectors arranged in a six element array. These detectors had to be liquid nitrogen cooled. Four arrays were set up so there were 24 channels of information. The unit employed a spun grating monochromator for fast scanning. In order to detect the 4 to 10 μm band, a mercury cadmium telluride detector was used.

Scott *et al.*, (1978) and Ridout and Webb (1980) both used an infrared imaging system for spatial plume scanning. This system employed an indium antimonide detector (liquid cooled), and a raster scanning prism system. The raster encoded signal could be displayed on a monitor, or be recorded on video tape. Scott *et al.* (1978) also used a commercial Fourier Transform Infrared Spectrometer for wavelength scanning.

Most existing systems are calibrated for temperatures below 1000°C, however, most rocket plumes are at temperatures greater than 3000°C. A general problem with imaging systems is that they give no spectral information. At this time there is no economical means of monitoring the IR emissions from plumes. This is especially true when dealing with new propellant formulations or new rocket designs and configurations, which are prone to catastrophic failure and can damage or destroy expensive equipment. Also, as tactical weapon systems become more sophisticated, spectral information for rocket motors and propellants becomes increasingly more important to those using them on and above the battlefield. The instrument we will describe is very simple and inexpensive compared to existing systems and provides useful spectral information. It can be used to characterize various rocket propellants and allow more insight into propellant combustion phenomena.

EXPERIMENTAL

The computer equipment used in our experiments included a Metrabyte DAS-20 analog-to-digital converter board installed in a COMPAQ 286 portable computer. The electronics-IR detector system was constructed based on designs first used by Hudson and Busch (1987, 1988), and later modified by Hudson *et al.* (1990). The radiometer used a lead selenide (PbSe) photoconductive cell as the sensing element (Hamamatsu P791-01). The sensitive area was arranged in a 1X3 mm slit shape. The radiometer employed a 600 Hz chopper motor and chopper frequency/phase reference circuit, one inch diameter Optical Coating Laboratories narrow bandpass filters, with the bandpass centered for either 2.7 μm or 4.45 μm, an aperture for field-of-view limitation, a preamplifier circuit, and a dedicated synchronous detector of our own design (Mofidi, *et al.*, 1991). The radiometer was mounted on a rigid metal base which serves as an optical rail. This enabled the accurate aiming of the overall system. Fig. 2 shows the experimental arrangement for the filter radiometer.

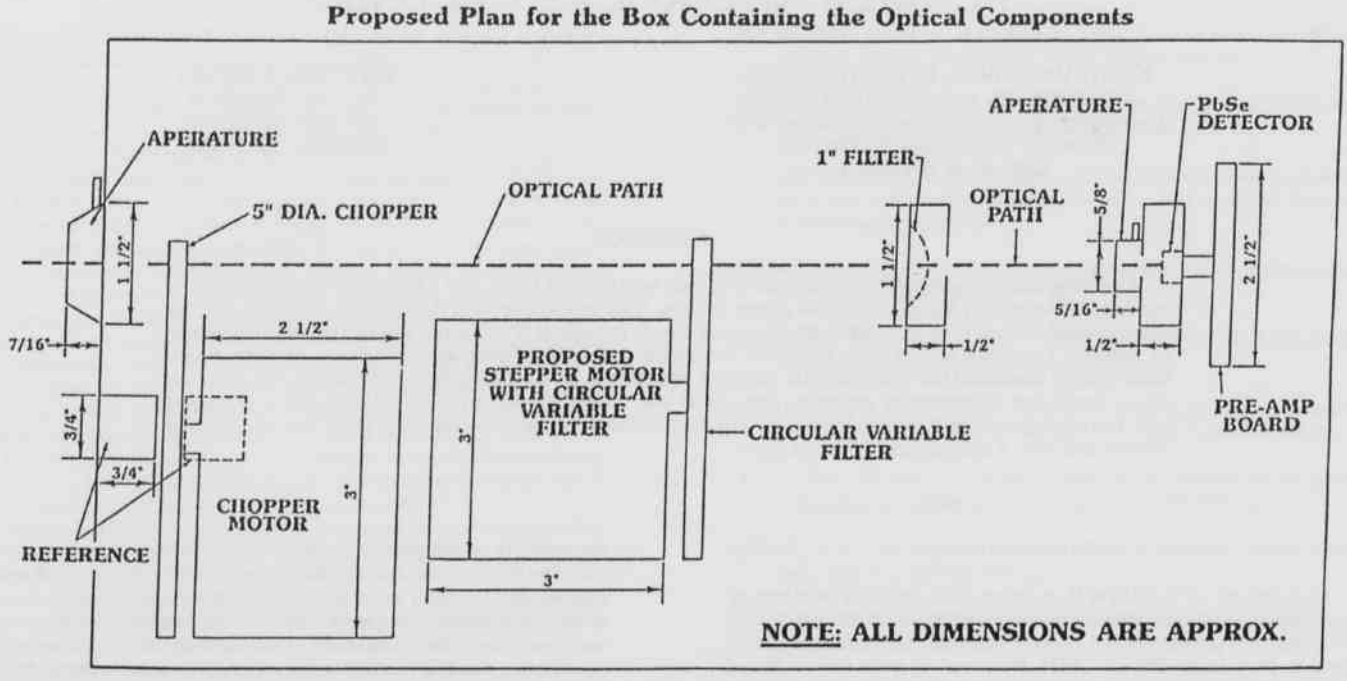

Figure 2. Dimensioned drawing of the IR radiometer, including proposed circularly variable filter placement.

The building where the rocket test motors were fired was approximately 100 ft. from the control bunker. The motors were mounted in a steel cradle, parallel to the ground, and connected to ignition cables stretched from the bunker for computer controlled firing. An approximately 36 volt pulse was sent from a control board in the bunker to the rocket motor to start the ignition process. This same pulse was used to trigger the analog-to-digital board to begin sampling data. The data were stored in a voltage vs. time (in seconds) format. Data were also obtained simultaneously from a pressure transducer on the rocket motor. All of the data were then saved to disk. Data were collected for several rocket propellants including: a "low smoke" formula, a high specific impulse formula, and an experimental formula. The experimental formulation was the subject of 15 experimental trials.

A Perkin-Elmer atomic absorption burner was modified to allow the introduction of organic compounds via its nebulizer, into an acetylene/air based flame (other fuels may be used such as hydrogen/air). Flame fuel and oxidant were controlled using Cole-Parmer flow meters with integral flow valves. The burner system was used to ascertain the response of the radiometer to specific functional groups and also to solutions of inorganic compounds.

RESULTS AND DISCUSSION

RADIOMETER DESIGN AND PERFORMANCE

The purpose for building this prototype radiometer was to show the feasibility of using a lead selenide detector, in conjunction with relatively simple electronic circuits, to inexpensively detect spectral emissions from flames and plumes. The PbSe IR detector has several advantages for detection of the 1.5 to 5.5 μm region, when compared to other IR detectors. A PbSe detector is a photoconductive cell, which works on the basis of the photoelectric effect. As the cell is irradiated, electrons are promoted from the valence band to the conduction band. This increase in charge carries is sensed as a voltage difference across the cell, when a constant bias voltage is applied across the cell through a fixed resistor in series with it. The PbSe detector can be used at room temperature with high sensitivity. This eliminates the need for expensive and bulky cooling methods. The detector is housed in a standard TO-5 transistor case, and was readily installed in the radiometer system. The radiation is chopped via mechanical chopper (600 Hz), so the resulting voltage is detected using AC circuits, and a dedicated synchronous detector substituted for the usual lock-in-amplifier. The chopping rate was chosen to be above the flicker noise threshold of the PbSe detector (about 500 Hz). The system could be operated in the DC mode, however, stability and sensitivity would be compromised.

One inch narrow bandpass filters were used because of ready availability and ease of replacement. Center frequencies were chosen to match as closely as possible the gas emission band maximums for carbon dioxide and water vapor at plume temperatures. Bandwidths at both wavelengths were chosen as narrow as were available in order to achieve maximum blackbody emissions rejection. Particles from the solid propellant materials emit a continuum spectrum, normally of less intensity than the gaseous band emissions. However, if the bandpass is too large the PbSe will respond more to the blackbody emission, since it integrates the total signal incident on its active surface. A 2.7 μm filter with a bandpass of 0.2 μm was used for water vapor and a 4.45 μm with a bandwidth of 0.5 μm was used for carbon dioxide.

Two problems were encountered with the use of the one inch filters. To change bands, the radiometer had to be disassembled, therefore the radiometer could not be scanned to record a spectrum. To allow spectral scanning and the changing of wavelengths without disassembly, future systems will replace the one inch bandpass filters with a circular variable filter. These filters are constructed in a circular shape, with different coatings of varying thickness along the curve. The effect is somewhat like that of a filter wedge, except that wavelength is varied linearly with angular displacement. These filters will be placed in a circular mount turned by a computer controlled stepper motor. This arrangement will give a great deal more versatility to the radiometer.

Apertures to limit field-of-view were used at the entrance to the radiometer and directly in front of the PbSe detector. Due to the slit shape of the PbSe active area and because of the placement of the rear aperture, it was expected that its use would change the shape of the viewed solid

angle of the plume of flame. The smallest opening was about 1.2 mm in diameter. Considering the 1X3 mm detector area, this would allow a circular image to be viewed. Opening the aperture would allow the entire 1X3 area to view the plume, and would correspond to a rough oval image, giving about a 3x increase in signal level. The front aperture would modify the size of the image, or viewed area. This aperture could vary in opening diameter between about 1.2 and 6 mm, allowing a large effect on viewed solid angle, and therefore, available light. It was found during the experimental trials that the front aperture did have a great effect, seen as apparent changes in orders of magnitude of signal level. With the high intensities from the rocket plumes, this aperture was set at about 2 mm. This allowed the use of most of the electronic circuit's dynamic range. The rear aperture was set at 3 mm, giving an oval viewed field.

The electronic circuits used in the radiometer were designed to be rugged, small, and offer good performance as an overall package. The circuit board was mounted to the side of the optical bench, near the PbSe device. This enabled short leads to be used in connections to the detector, minimizing noise pick-up. The circuit included a signal pre-amplifier, chopper reference comparator, and a synchronous detector. This circuit replaced a lock-in-amplifier, giving a radiometer package that was truly portable. Operation of the circuitry gave sufficient sensitivity for the moderate to high intensity emissions viewed by the radiometer, while allowing sufficient dynamic range for all rocket firing after initial settings were made. All of the experimental trials were run with a time constant of 250 milliseconds (msec) hardwired on the circuit board. A shorter time constant would have revealed more plume intensity detail. This fact was not apparent until rocket motor data was taken using the radiometer in conjunction with the existing pressure system. Analysis of pressure data indicates changes occurring on a time scale closer to 10 msec. Future studies will characterize an optimum time constant. This circuitry is described in more detail in another submission to this Journal (Mofidi, *et al.*, 1991).

FLAME COMBUSTION STUDIES

The atomic absorption burner was used to initially test the radiometer and assess its performance. Burner studies were done with a front aperture diameter of about 5 mm. The acetylene/air flame was adjusted to give fuel rich, stoichiometric, and lean flames. The emission from the burner was monitored using each filter, allowing a comparison of the water and carbon dioxide bands. Also, organic compounds containing various functional groups were aspirated into the flame for combustion. The relative contribution of functionality to the emission in each band was noted. In addition, several aqueous solutions of metals were aspirated, at levels from 250 to 1000 ppm. These metals had no effect on IR signal, under these conditions. Metals are commonly used to modify rocket plume signatures and propellant burn rates. Effects of organic groups and metals will be investigated further.

ROCKET PLUME STUDIES

The radiometer was positioned with the entrance aperture located 18 inches from the plume. For this preliminary set of experiments, the radiometer was mounted on a wooden box under the plume and "looked" up into the plume. Concerns that particles or burning pieces of insulation might fall into the radiometer were unfounded. Evidently, the combination of high burn velocity and temperature caused any particulate matter to be ejected forcefully out of the test stand. The radiometer location was varied from two to approximately 30 inches from the rocket nozzle, in order to view different portions of the plume. The curves generated were very similar, with a decrease in IR intensity seen as the unit moved further from the rocket nozzle. It was expected that the 4.4 μm, CO_2 signal would have gone through a maxima as the distance to the nozzle was increased, due to afterburning with atmospheric oxygen. It is possible that this was not observed because of the aperture size and image resolution employed, or because of the formulation of the propellant mixtures used. This effect will be more thoroughly studied in future work.

Several pressure vs. IR plots were made and analyzed. These plots illustrate that the IR emissions at 4.4 μm generally agree with the internal pressure data. As the pressure rises, the thrust increases, and the overall burn time decreases. Figs. 3-5 generally show this behavior. Note that the

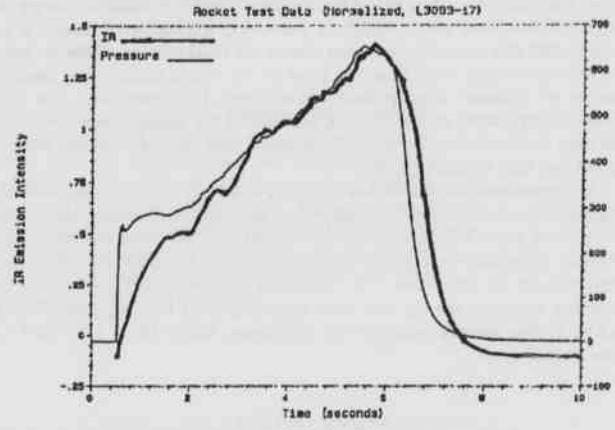

Figure 3. Normalized pressure/IR rocket test data (L3093-17).

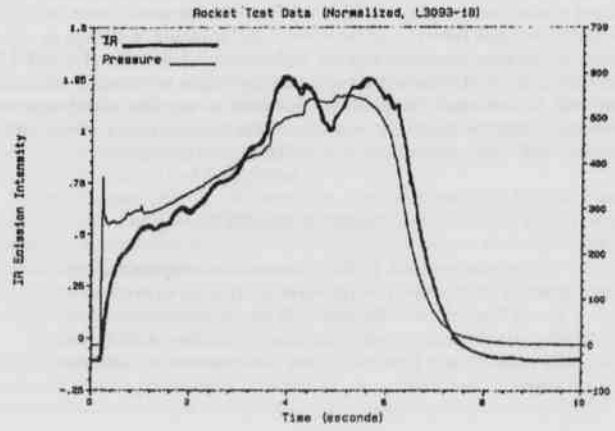

Figure 4. Normalized pressure /IR rocket test data (L3093-18).

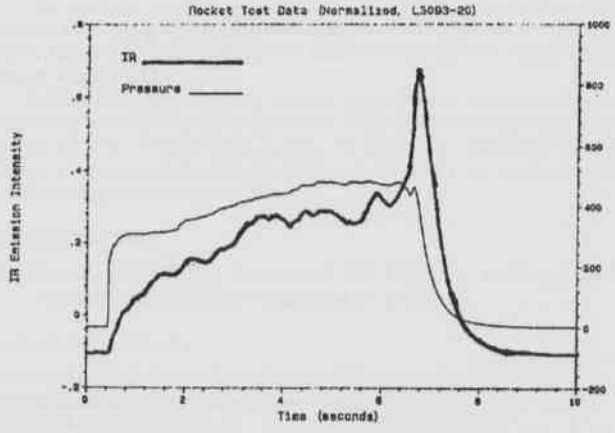

Figure 5. Normalized pressure/IR rocket test data (L3093-20).

pressure rises rapidly at rocket ignition, while the IR data slopes up more slowly. Much of this effect is due to the 250 msec time constant effectively smoothing out differences. This is also seen at burn-out. However, the IR data indicate greater magnitude fluctuations in each figure, especially in Fig. 5. The IR data for Fig. 5 indicates a sharp rise in emission just before burn-out. This was noted by the operators as an audible change in rocket exhaust note pitch, which is somewhat indicative of thrust. It is thought that this anomaly was seen due to the final portion of the propellant casting tearing loose from the front of the rocket motor inner casing, causing an increase in propellant surface area. It is interesting that this effect was indicated in the IR data, and not in the internal pressure data, and may indicate that the propellent piece may have exited the rocket nozzle just after breaking loose.

A comparison was also made between a "smoky" and a clean burning propellant formulation, as currently used in weapons systems, using two trial runs of each. While not entirely conclusive, these runs indicated that a visible difference in particle emissions, or smoke, does not allow the prediction of IR emissions. The evidently defacto industry standard of watching or video taping trial runs cannot predict the "signature" of a rocket. It also cannot quantify the emissions, either IR or UV-Visible, from the motor.

CONCLUSIONS

The authors feel that the radiometer with future improvements will provide an excellent and inexpensive basis for spectral data collection. Future studies will employ changes in the areas discussed above, mainly: circularly variable filters to allow wavelength scanning, a change in electronic circuit time constant, and the collection of data at the 4.4 and 2.7 μm carbon and hydrogen wavelengths during rocket burn. Also, emission data will be collected for particle emissions at another wavelength to investigate the blackbody IR signature. This type data may reveal more about the efficiencies of different propellant formulations.

ACKNOWLEDGMENTS

The authors wish to thank Hercules Aerospace for support of this project. Appreciation is also expressed to David Wankum and Reagan Cole for suggestions on optics and electronics, and to Armand Tomany and Lewis Neidhart of the Electronics and Instrumentation Machine Shop.

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A SURVEY AND ANNOTATED CHECKLIST OF THE LATE SUMMER FLORA OF THE MOIST SOIL UNITS AT HOLLA BEND NATIONAL WILDLIFE REFUGE

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ABSTRACT

We conducted a floristic survey of 22 moist soil units at Holla Bend National Wildlife Refuge during September and October of 1990. The moist soil units range in size from 0.4 to 9.7 ha and are depressions manipulated to provide food and shelter for waterfowl. In total, 60 taxa representing 24 families and 42 genera were identified and are compiled into an annotated checklist. The flora was dominated by the following families and genera in decreasing order of importance: Asteraceae *(Xanthium)*, Polygonaceae *(Polygonum)*, and Amaranthaceae *(Amaranthus)*. The Poaceae and the Cyperaceae were well represented, but were of lesser importance. Twenty-three of the collections represent new records for Pope County and voucher specimens have been placed in the Arkansas Tech University Herbarium (APCR). The checklist and abundance data will benefit Refuge personnel in management of the units.

INTRODUCTION

Holla Bend National Wildlife Refuge is located along the Arkansas River about 8 km southeast of Dardanelle, Arkansas in Pope and Yell counties. In the early 1900s, over 65 families resided in the area and farmed the rich bottomland soil. A disastrous flood inundated the area in 1927; that event and subsequent floods deposited up to four feet of sand and the land was abandoned.

The 2547 ha refuge was formed when the Corps of Engineers cut a new channel across an oxbow and transferred the land to the U.S. Fish and Wildlife Service in 1957. Farming acreage was cleared and soil conservation practices were begun, but the soils remain very sandy and drought-prone. Cropland manipulation is the current management tool on the refuge which consists of one-half cropland and one-half woodlands and water. The purposes of the refuge are to provide the following: habitat for wintering waterfowl; habitat for endangered species; habitat for resident wildlife; and interpretation and recreation for the public.

We conducted a survey of the most soil units on the refuge to provide the U.S. Fish and Wildlife Service with a listing of plants and to estimate the abundance of each species. Within the study area, a secondary objective was to determine which of these plants, if any, are known to be of benefit to waterfowl.

A moist soil unit (MSU) is a depression on a non-wooded area that can hold standing water at least temporarily. Water levels vary with precipitation and most MSUs are not permanently wet, although a few are intentionally flooded during the winter months for the benefit of the waterfowl. Most of the MSUs are periodically cultivated.

METHODS

The first author made weekly collections from 22 of the 29 MSUs during September and October of 1990. Seven of the units were returned to cultivation before collecting began. In addition to general collections, plots of 1 m^2 were randomly sampled to estimate species abundance. Voucher specimens have been placed in the Arkansas Tech University Herbarium (APCR).

References used extensively for plant identification, nomenclature, and distribution data were: Steyermark (1963); Radford *et al.* (1968); Godfrey and Wooten (1979); Cronquist (1980); Godfrey and Wooten (1981); Smith (1988); and Isely (1990). Waterfowl usage of plants was determined by consulting Martin *et al.* (1961) and Ocean Data Systems (1978).

RESULTS

We have compiled a checklist of 60 taxa representing 24 families and 42 genera from the collections of the first author. Families with the largest number of species in the flora were the Poaceae (12 species), Cyperaceae (9 species), Asteraceae (5 species), Polygonaceae (4 species), and the Amaranthaceae (4 species). The largest genera in the flora include *Cyperus* (5 species) and *Polygonum* (4 species).

The Poaceae and the Cyperaceae are the dominant families and *Cyperus* and *Polygonum* are the dominant genera of the MSUs with respect to the number of taxa. But, in number of plants, the MSU flora is dominated by *Xanthium strumarium* (25%), *Polygonum* spp. (16%) and *Amaranthus* spp. (12%). The flora of the MSUs depends on management practice, precipitation and the opportunistic nature of the plants.

Not surprisingly, the flora of the MSUs consists of many "weedy" species due to the nature of the area. Although many of the plants are common and of widespread distribution, our collections include 23 additions to the known flora of Pope County, as indicated by Smith (1988).

ANNOTATED CHECKLIST

The checklist is arranged alphabetically according to family, genus, species and variety to facilitate use by interested individuals. Family concepts follow Cronquist (1988) and nomenclature follows Smith (1988) except where noted.

Entries have the following format: taxon name, author, vernacular name (when available) and an indication if the collection represents a new record for Pope County (NR). Lastly, the collection number of the first author is given which may be followed by notes on nomenclature, wildlife usage or distribution data.

ALISMATACEAE

Sagittaria latifolia Willd.; Arrowhead; NR; 288; only seeds and corms are utilized by waterfowl (Martin *et al.*, 1961).

AMARANTHACEAE

Amaranthus rudis Sauer; Water Hemp; 239.
A. tuberculatus (Moq.) Sauer; Water Hemp; NR; 223.
Amaranthus sp.; 279.
Froelichia floridana (Nutt.) Moq. var. *campestris* (Small) Fern.; Cottonweed; 266.

APOCYNACEAE

Trachelospermum difforme (Walt.) Gray; Climbing Dogbane; 252.

ASTERACEAE

Ambrosia trifida L.; Giant Ragweed; 318.
Aster lanceolatus Willd. (incl. *A. simplex* Willd.) Tall White Aster; 235.
Eclipta alba (L.) Hassk.; Yerba de Tajo; 219; nomenclature follows Cronquist (1980).
Solidago rupestris Raf.; Goldenrod; 257; nomenclature follows Cronquist (1980).
Xanthium strumarium L.; COCKLEBUR; 203.

BORAGINACEAE

Heliotropium indicum L.; Indian Heliotrope; 322.

BRASSICACEAE

Rorippa palustris (L.) Besser subsp. *glabra* (O.E. Schultz) Stuckey var. *fernaldiana* (Butt. & Abbe) Stuckey; Marsh Yellow Cress; 250.

CAESALPINIACEAE

Chamaecrista fasciculata (Michx.) Greene; Partridge Pea; 259; nomenclature follows Isely (1990).
Senna obtusifolia (L.) Irwin & Barneby; Sicklepod; 309; nomenclature follows Isely (1990).

CYPERACEAE

Cyperus aristatus Rottb.; NR; 311.
C. erythrorhizos Muhl.; Redroot Flatsedge; NR; 217.
C. esculentus L.; Yellow Nutsedge; NR; 245; only rhizomes are utilized by waterfowl (Ocean Data Systems, 1978).
C. iria L.; Umbrella Sedge; NR; 229.
C. odoratus L.; NR; 267V.
Eleocharis microcarpa Torr.; NR; 227; only seeds and rhizomes are utilized by waterfowl (Martin *et al.*, 1961); this collection represents a significant expansion to the known distribution in Arkansas indicated by Smith (1988).
E. obtusa (Willd.) Schultes; Blunt Spike Rush; NR; 314; only seeds and rhizomes are utilized by waterfowl (Martin*et al.*, 1961).
Eleocharis sp.; 287; only seeds and rhizomes are utilized by waterfowl (Martin *et al.*, 1961).
Fimbristylis sp.; 293.

EUPHORBIACEAE

Acalypha rhomboidea Raf.; Three-seeded Mercury; 301.
Euphorbia maculata L.; Nodding Spurge; 285.
E. supina Raf.; Milk Purslane; 238.

FABACEAE

Sesbania exaltata (Raf.) Cory; Hemp Sesbania; 299; nomenclature follows Isely (1990); only seeds are utilized by waterfowl (Ocean Data Systems, 1978).

LAMIACEAE

Hedeoma pulegioides (L.) Pers.; Pennyroyal; 255.

LYTHRACEAE

Ammannia x *coccinea* Rottb.; Purple Ammannia; 212.

MALVACEAE

Sida spinosa L.; Prickly Sida; 262.

MOLLUGINACEAE

Mollugo verticillata L.; Carpet-weed; 261.

NYMPHAEACEAE

Nelumbo lutea (Willd.) Pers.; American Lotus; NR; 230; only seeds and roots are utilized by waterfowl (Martin *et al.*, 1961).

ONAGRACEAE

Ludwigia decurrens Walt.; Primrose Willow; NR; 224.
L. peploides (H.B.K.) Raven subsp. *glabrescens* (Kuntze) Raven; Floating Primrose Willow; 284.
Oenothera sp.; 316.

POACEAE

Brachiaria platyphylla (Griseb.) Nash; Signalgrass; NR; 209; significant expansion of known distribution (Smith, 1988).
Digitaria filiformis (L.) Koel. var. *filiformis;* Slender Crabgrass; 295.
D. sanguinalis (L.) Scop.; Hairy Crabgrass; NR; 277.
Echinochloa crusgalli (L.) Beauv.; Barnyard Grass; 204; only seeds are utilized by waterfowl (Ocean Data Systems, 1978).
E. muricata (Beauv.) Fern.; Barnyard Grass; NR; 306.
Hordeum pusillum Nutt.; Little Barley; 255.
Leptochloa fascicularis (Lam.) A. Gray; Bearded Sprangletop; NR; 247; significant expansion of known distribution (Smith, 1988).
L. uninervia (Presl) H. & C.; Mexican Sprangletop; NR; 210; significant expansion of known distribution (Smith, 1988).
Paspalum paspaloides (Michx.) Scribn.; Knotgrass; NR; 289; significant expansion of known distribution (Smith, 1988); only seeds are utilized by waterfowl (Martin *et al.*, 1961).
Setaria geniculata (Lam.) Beauv.; Knotroot Bristlegrass; 252; only seeds are utilized by waterfowl (Ocean Data Systems, 1978).
Sorghum halepense (L.) Pers.; Johnson Grass; 321; only seeds are utilized by waterfowl (Ocean Data Systems, 1978).
Sphenopholis obtusata (Michx.) Scribn.; Prairie Wedgescale; 244.

POLYGONACEAE

Polygonum densiflorum Meisn.; Smartweed; NR; 221; only seeds are utilized by waterfowl (Martin *et al.*, 1961).
P. hydropiperoides Michx.; Wild Water Pepper; 213; only seeds are utilized by waterfowl (Martin *et al.*, 1961).
P. lapathifolium L.; Pale Smartweed; NR; 211; only seeds are utilized by waterfowl (Martin *et al.*, 1961).
P. pensylvanicum L. var. *laevigatum* Fern.; Pinkweed; NR; 207; only seeds are utilized by waterfowl (Martin *et al.*, 1961).
P. pensylvanicum L. var. *pensylvanicum;* Pinkweed; NR; 206; only seeds are utilized by waterfowl (Martin *et al.*, 1961).

ROSACEAE

Rubus sp.; 286.

SAPINDACEAE

Cardiospermum halicababum L.; Balloon Vine; 236.

SCROPHULARIACEAE

Conobea multifida (Michx.) Benth.; 254.

SOLANACEAE

Physalis angulata L.; Ground Cherry; NR; 225.
P. longifolia Nutt.; Ground Cherry; 310.

URTICACEAE

Pilea pumila (L.) A. Gray; Clearweed; NR; 302.

VITACEAE

Ampelopsis arborea (L.) Koehne; Pepper Vine; 258.

ACKNOWLEDGMENTS

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GENERAL NOTES

HOMOGENOUS FUNCTIONS IN THERMODYNAMICS

Historically, the laws of thermodynamics were developed using phenomenological methods; the statements of these laws, and of the results deduced from them, were framed in terms of macroscopic mechanical systems. The teaching of thermodynamics has traditionally followed this historical, phenomenonological approach. This approach is exemplified by the classic book by Zemansky and Dittman (1981). Traditional courses in thermodynamics have followed this historical development and have, as a result, been devoted to purely macroscopic concepts.

The microscopic science of statistical mechanics has largely been developed in this century and until recently it was covered in a separate course. In recent years it has becoine increasingly common to treat macroscopic thermodynamics and microscopic statistical mechanics in a single course, this course is usually called thermal physics. This means that the traditional, languid introduction to macroscopic thermodynamics can no longer be used and a different approach is needed. The study of thermodynamics can be shortened by using a system of axioms instead of the phenomenonological approach.

Several attempts have been made to provide thermodynamics with an axiomatic basis, the most widely used system of axioms was developed by Callen (1960). This paper will not explicitly deal with these axioms, the interested reader is referred to the book by Callen or to the more recent book by Tien and Lienhard (1985). In the axiomatic approach to thermodynamics, the question of whether a thermodynamic variable is *extensive* or *intensive* is emphasized. This paper concentrates on the relationship between homogenous function theory and extensive and intensive thermodynamic variables, and it develops a method of calculating the thermodynamic properties of N moles of a material if an equation is known for some fixed amount of that material.

HOMOGENEOUS FUNCTIONS

As the properties of homogeneous functions are not well known, their major properties are presented in detail in this section.

We shall consider functions which are homogenous in terms of functional equations. The functional equations appropriate to the study of homogeneous functions were developed by Euler (1755, 1768, 1770); Aczel (1966, 1969), Davis (1960), Stanley (1971), and Widder (1961) provide modern introductions, of varying degrees of sophistication, to the subject of functional equations.

A function f(x) is a homogeneous function if for all values of the parameter λ,

$$f(\lambda x) = g(\lambda) f(x) .$$

Where the function g(l) is usually called the scaling function in thermodynamics. Stanley (1971) has shown at the function g(l) is not an arbitrary function, instead g(l) is given by

$$g(\lambda) = \lambda^n .$$

Thus, a homogeneous function f(x) of degree n is a function in which

$$f(\lambda x) = \lambda^n f(x) .$$

This definition can be generalized to any finite number of variables. The degree n can take on any value – positive, negative or zero. It is possible for functions to be homogeneous of different degree in different variables. This is true of some of the functions which occur in thermodynamics.

If we have a function of the variables x, y and z, f(x,y,z), and if for this function,

$$f(x, \lambda y, \lambda z) = \lambda^n f(x,y,z) ,$$

then we say that this function is homogeneous of degree n in e variables y and z.

The idea of homogeneous functions admits further generalization (Stanley, 1971); a function f(x,y) is called a generalized homogeneous function if

$$f(\lambda^a x, \lambda^b y) = \lambda f(x,y) .$$

It is this generalized formulation that is used in the analysis of critical point phenomena and phase transitions using the static scaling hypothesis. The reader should note that

$$f(\lambda^a x, \lambda^b y) = \lambda^p f(x,y)$$

is not a further generalization. This is clear since, by choosing $\lambda^p = \Lambda$ we can rewrite the equation as

$$(\Lambda^{a/p} x, \Lambda^{a/p} y) = \Lambda f(x,y) .$$

We can now choose p = 1 without loss of generality and observe that this form is equivalent to the original definition of a generalized homogeneous function.

In the rest of this paper I will restrict my attention to functions which are homogeneous of degree zero or order one. It is these simpler cases that are useful in elementary thermodynamics.

EXTENSIVE AND INTENSIVE THERMODYNAMIC VARIABLES

The variables which occur in thermodynamics are either *extensive* or *intensive*.

The internal energy (E) of a thermodynamic system is an example of an extensive variable. If a variable is described as *extensive* then that variable depends linearly on the size of the system. In other words, if a system is composed of several sub-systems, the value of the extensive quantity for the composite system is calculated by summing over the sub-systems. As an example, if a system is composed of a sub-system of internal energy E1, and a second sub-system of energy E_2, then the energy of the composite system is $E = E_1 + E_2$. We may state this property succinctly by stating that *extensive quantities are additive over a set of sub-systems*. Other extensive variables that occur in thermodynamics are: volume (V), mole number (N), entropy (S), enthalpy (H), Helmholtz free energy (F), and Gibbs free energy (G).

Some variables that occur in thermodynamics are independent of the size of the system, these variables are called *intensive* variables. The intensive variables of thermodynamics are temperature (T), pressure (p), and the chemical potential of the i^{th} component of the system (μ_i).

General Notes

THE RELATIONSHIP BETWEEN HOMOGENEOUS FUNCTIONS AND EXTENSIVE AND INTENSIVE VARIABLES

Entropy, which is an extensive variable, can be expressed as a function of three other extensive variables: internal energy, volume and number of moles. That is we may write S=S (E,V,N). An equation of this form contains complete thermodynamic information, it is called the *fundamental relation* in thermodynamics. Now, we have stated that extensive variables depend linearly on the size of the system, this means that extensive variables can be represented by homogeneous first degree functions. Thus, given S=S (E,V,N) we can immediately write

$$S(\lambda E, \lambda V, \lambda N) = \lambda S(E,V,N).$$

The scaling function l is arbitrary, and following Callen (1960) we will choose $\lambda = (1/N)$. The entropy equation can now be rewritten as

$$S\left(\frac{E}{N}, \frac{V}{N}, 1\right) = \frac{1}{N} S(E,V,N).$$

Next we introduce the internal energy per mole e = E/N, and the volume per mole v = V/N, and then

$$S(e,v,1) = s(e,v) = 1/N\ S(E,V,N)$$

or

$$N\ s(e,v) = S(E,V,N),$$

where s(e,v) is the entropy per mole. This tells us that the entropy of N moles of a substance is N times the entropy per mole of that substance. This result is well known, the method by which it was arrived at can be generalized to provide a result of more general utility. This will be done in the next section, first we will further investigate intensive functions.

The intensive functions of thermodynamics are homogeneous functions of order zero of the extensive variables. Callen (1960) shows that the intensive parameters of a thermodynamic system may be written as functions of the extensive variables in the following manner:

$$T = T(S,V,N)$$

$$P = P(S,V,N)$$

$$\mu = \mu(S,V,N).$$

These expressions for the intensive variable in rms of extensive variables are called *equations of state*. Each of these functions is homogeneous of degree zero, this follows as each of these can be expressed as a first partial derivative of the energy or entropy of the system. The details can be found in Chandler (1987). We will consider temperature as an example, for the temperature function T(S,V,N),

$$T(\lambda S, \lambda V, \lambda N) = T(S,V,N).$$

This means that in a composite system in thermal equilibrium the temperature in any sub-system is equal to the temperature of the system.

THEOREM

Consider a function f(x,y,x) that is homogeneous of degree n in the variables y and z. That is,

$$f(x, \lambda y, \lambda z) = \lambda^n f(x,y,z).$$

Now if we let $z = z_o$, we may write

$$f(x,y,z_o) = g(x,y),$$

where g(x,y) is the value of f(x,y,z) at Z = Zo.
Then

$$f(x,y,z) = \left(\frac{Z}{Z_o}\right)^n g\left(x, y\frac{Z_o}{Z}\right),$$

where Z and Zo are non-zero.
This result can be proved as follows. First we write f(x,y,z) as

$$f(x,y,z) = \left(\frac{Z}{Z_o}\right)^n \left(\frac{Z_o}{Z}\right)^n f(x,y,z).$$

By choosing $\lambda = z_o/z$ we can rewrite this equation using the fact that it is homogeneous of degree one in the variables y and z, so we have

$$f(x,y,z) = \left(\frac{Z}{Z_o}\right)^n f\left(x, y\frac{Z_o}{Z}, z\frac{Z_o}{Z}\right) = \left(\frac{Z}{Z_o}\right)^n f\left(x, y\frac{Z_o}{Z}, Z_o\right).$$

Now, Zo is a constant so clearly we may write

$$f\left(x, y\frac{Z_o}{Z}, Z_o\right) = g\left(x, y\frac{Z_o}{Z}\right),$$

resulting in,

$$f(x, y, z) = \left(\frac{Z}{Zo}\right)^n g\left(x, y\frac{Zo}{Z}\right),$$

which is our stated theorem.

APPLICATIONS TO EXTENSIVE QUANTITIES

This theorem can be used in a variety of situations, we will consider some examples of its application. We will first consider the case when the degree of homogeneity is one.

First a trivial example. Given that the internal energy of a system for 3 moles of a substance is $E = pV^2$, what is the internal energy for N moles? We proceed as follows, we want E(p,V,N). The form of the theorem in this case is:

$$E(p, V, N) = \left(\frac{N}{N_o}\right) g\left(p, V\frac{N_o}{N}\right),$$

where $g(p,v) = pV^2$, and $N_o = 3$.
So,

$$E(P, V, N) = \frac{N}{3}\left\{P\left(\frac{V3}{N}\right)^2\right\} = 3\frac{pV^2}{N}.$$

As a second example, consider that the entropy of one mole of some substance is given by

$$s = R \ln (E^{3/2}V) + C.$$

Where C is a constant. What is the entropy for N moles of this material. Care must be exercised in this case because S is homogeneous of degree one in both E and V. This time we can write

$$S = \frac{N}{N_o}\left\{R \ln\left[\left(\frac{E N_o}{N}\right)^{3/2} \frac{V N_o}{N}\right] + C\right\},$$

but $N_o = 1$ so we get the result

$$S = N R \ln (E^{3/2} V N^{-5/2}) + NC.$$

APPLICATIONS TO INTENSIVE QUANTITIES

To apply the theorem to intensive quantities we set n, the degree of homogeneity, equal to zero in the theorem.
Again we will let the number of moles N play the role of the coordinate z so that $Z_o = N_o$.
Given the van der Waals equation of state for a single mole of gas,

$$p = \frac{RT}{V-b} - \frac{a}{V^2},$$

where *R* is the ideal gas constant and *a* and *b* are constants. What is the van deer Waals equation of state for N moles? In this case the theorem becomes:

$$p(T, V, N) = p\left(T, V\frac{N_o}{N}\right),$$

so the pressure for N moles is:

$$p = \frac{RT}{\frac{V}{N}-b} - \frac{a}{(V/N)^2} = \frac{NRT}{V-Nb} - \frac{N^2a}{V^2}$$

This is of course the van der Waals equation for N moles.

DISCUSSION AND CONCLUSIONS

This paper has demonstrated the usefulness of homogeneous functions in thermodynamics. I have used the theorems presented in this paper in my thermal physics course for several years. I have found that a study of these theorems circumvents the usual tendency of students to scale thermodynamic results incorrectly. The theorems presented herein provide a deeper understanding of the relationship between the fundamental relation of thermodynamics and the equations of state.

The methods of functional equations are extremely useful in the analysis of critical point phenomena, and while the methods are not well known, they have been applied to other sub-fields of physics. Some examples are the applications to relativity by Lunn (1919), to communication theory by Shannon (1948a

and 1948b), and to information theory by Haynes (1957). These applications, in addition to the applications mentioned previously, suggest that physicists should become more familiar with the techniques of application of functional equations. The theorem derived in this paper is useful for calculating general results from measurements made on fixed amounts of materials. The methods developed in this paper allow the student to develop an understanding of the mathematical techniques used in the application of homogeneous functions; this allows these students to concentrate on the physics of critical point phenomena when they are first met, thus affording a deeper understanding.

ACKNOWLEDGMENTS

This paper was written to honor the teaching career of Dr. Robert E. Kelly, formerly of the University of Mississippi, and currently at Los Alamos Scientific Laboratories. It was in his classroom that I learned the axiomatic approach to thermodynamics and much else. The basic methods of this paper were taught by Dr. Kelly for many years, though the particular forms and proofs presented above are due to the present author.

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A SYNOPSIS OF THE NOTONECTIDAE OF ARKANSAS

There have been no studies pertaining specifically to the Notonectidae (back swimmers) of Arkansas. Pertinent information is either in taxonomic studies which include Arkansas material (Hungerford, 1933; Truxal, 1953) or aquatic macroinvertebrate lists from particular sites in the state (Harp and Hubbard, 1972; Harp and Harp, 1980; Farris and Harp, 1982; Huggins and Harp, 1983). The purposes of this paper are to present the first statewide species list, to delineate geographic distributions and to define preferred habitats for notonectid species in this state. Arkansas species may be identified by using Froeschner's (1962) key to Missouri species.

Most data presented have been synthesized from specimens in the Aquatic Macroinvertebrate Collection of the Arkansas State University Museum of Zoology; however contributions from museum collections from the Universities of Arkansas-Fayetteville and -Little Rock, along with literature records, are included. Supplemental collections were made by the authors to diminish distributional gaps in the data.

Two genera encompass the eight species of Notonectidae that occur in Arkansas. All species undergo five nymphal instars to reach adulthood and pass the winter as adults. Species of the two genera differ with respect to respiration, however. *Notonecta* species must surface frequently to replenish their oxygen supply. *Buenoa* individuals, however, have hemoglobin-filled abdominal sacs which greatly increase their capacity to store atmospheric oxygen (Truxal, 1953). This difference allows *Buenoa* to inhabit deeper water farther from shore and probably explains in part why fewer specimens of this genus are collected.

Buenoa confusa (Truxal) was first reported from Arkansas by Harp and Hubbard (1972). Distributionally, it is our least common notonectid, being represented by 35 specimens from 11 collections in three counties (Fig. 1). The collection in Monroe Co. contained three specimens taken by a black light trap. All other specimens were taken from the remaining two counties and were collected with a dipnet. Wilson (1958) reported this species in Mississippi from a single brackish pool filled with vegetation. In Arkansas, all collections were taken from clear, acid bauxite lakes, clear lakes or ponds with vegetation present. Arkansas collections thus far are from three ecoregions: Crowley's Ridge, the Ouachitas and the Mississippi Alluvial Plain. Truxal (1953) reported this species has been collected every month except February, March, October and December. Arkansas specimens have been collected during May and July-October.

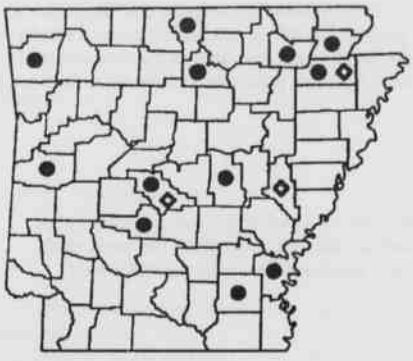

Fig. 1. B. confusa ◇
B. margaritacea ●

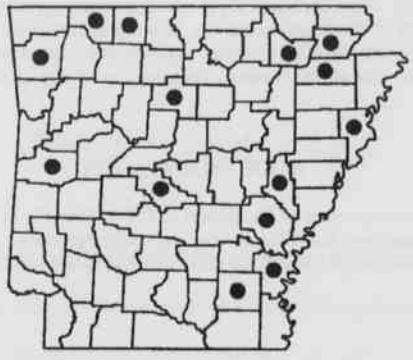

Fig. 2. B. scimitra

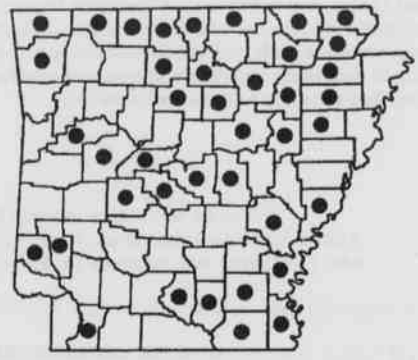

Fig. 3. N. indica

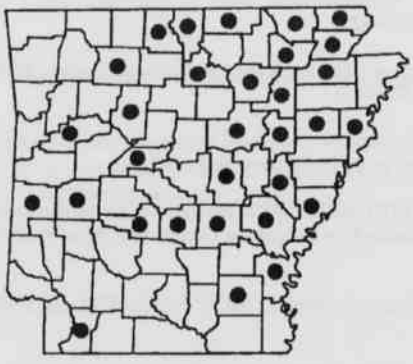

Fig. 4. N. irrorata

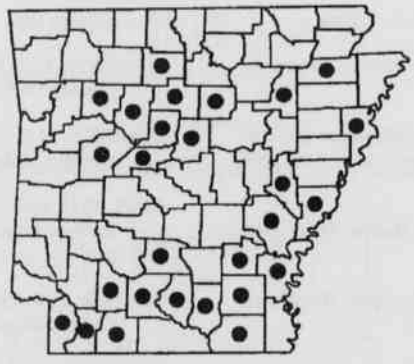

Fig. 5. N. raleighi

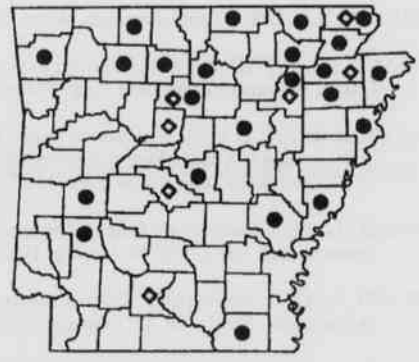

Fig. 6. N. uhleri ◇
N. undulata ●

Buenoa margaritacea (Torre-Bueno) was first reported from Arkansas by Truxal (1953). It is known from 35 specimens in 20 collections from 12 counties (Fig. 1). It has been taken in all of Arkansas' ecoregions except the Gulf Coastal Plain. Wilson (1958) reported that in Mississippi this species was most commonly collected from ponds. The only records for Missouri of this species came from Truxal's (1953) revisionary study (Froeschner, 1962). Most Arkansas specimens have been taken from ponds or lakes. However, specimens have also been taken from a pool area of Black River, a stream, roadside ditches and borrow-pits. Truxal (1953) reported collections of this species from every month of the year. Arkansas collections have been taken during February-May, July-September and November.

Buenoa scimitra (Bare) was first reported from Arkansas by Truxal (1953). It is the most common species of this genus in Arkansas, being known from 163 individuals in 29 collections from 14 counties (Fig. 2). Like *B. margaritacea*, *B. scimitra* has been collected from all five ecoregions of Arkansas except the Gulf Coastal Plain. Only in recent collections has this species been taken in large numbers in the state. Wilson (1958) and Froeschner (1962) reported this species to be the most common *Buenoa* in Mississippi and Missouri, respectively. Wilson (1958) reported this species to prefer sparsely vegetated, muddy, roadside pools, streams, small ponds and borrow-pits. Arkansas collections have been from these same habitat types. It is very commonly collected in black light trap samples. Truxal (1953) reported this species was collected every month of the year. Mississippi specimens have been taken from March to December (Wilson, 1958). Missouri specimens were taken during July, August and November (Froeschner, 1962). Arkansas collections occurred during January-May, July, September and November.

Notonecta indica (Linnaeus) was first reported from Arkansas by Hungerford (1933). It is our most common and most plastic notonectid species, being known from 519 individuals from 115 collections in 40 of Arkansas' 75 counties (Fig. 3). It has been collected from all five ecoregions of Arkansas. Froeschner (1962) reported this species to be uncommon in Missouri. Conversely, Wilson (1958) reported it to be very common and widespread in Mississippi. He also noted a wide range of color patterns for this species. Alexander (1982) observed eight hemelytral color patterns exhibited by specimens from Arkansas. We have seen the color patterns for this species range from completely white to almost completely black. Wilson (1958) reported this species to be commonly collected from ponds, borrow-pits, and small streams. Arkansas specimens have been taken from most every type of aquatic environment, including swimming pools. Froeschner (1962) reported that in Missouri this species was taken in March, June and November. Hungerford (1933) reported that this species had been collected, as it has in Arkansas, every month of the year.

Notonecta irrorata (Uhler), the largest notonectid in Arkansas, was first reported from the state by Hungerford (1933). It is a common and widespread species, being represented by 217 individuals from 69 collections in 31 counties throughout the five ecoregions of Arkansas (Fig. 4). Froeschner (1962) reported it to be known in Missouri from a few specimens taken in the southeast corner of the state. This species is common and widespread in Mississippi and occurs in a wide range of aquatic habitats (Wilson, 1958). Hungerford (1933) reported this species to be most common in water shaded by vegetation or overhanging limbs. Arkansas specimens were collected in a wide range of aquatic habitats but most often from habitats similar to those described by Hungerford. In Missouri, this

species was taken during March and June (Froeschner, 1962). Hungerford (1933) reported this species was collected every month except January and February, but noted that it was observed swimming under ice in Ithaca, N.Y., during early February. Arkansas specimens have been taken every month except May.

Notonecta raleighi (Bueno) was first reported from Arkansas by Harp and Harp (1980). Materials at hand show 116 individuals in 48 collections in 27 counties (Fig. 5). It has been collected in all five ecoregions of Arkansas, but seems to be most common in the southern portion of the state. Foreschner (1962) reported this species to be uncommon in Missouri, being collected only from large ponds and a pool area of a nearly dry stream bed. Wilson (1958) reported this species to be fairly common in Mississippi, being taken from a wide range of aquatic habitats except for running streams and borrow-pits. Collections in Arkansas are from habitats similar to those reported by Wilson (1958). Missouri specimens of this species were taken during March, June and October (Froeschner, 1962). Arkansas specimens of this species have been collected every month except April, July and December.

Notonecta uhleri (Kirkaldy) has not previously been reported from Arkansas. It is the least common notonectid species in the state, being now known from only 12 individuals having been taken in eight collections from seven counties (Fig. 6). Of the eight collections, three were from the Ouachita Mountains, two were from Crowley's Ridge, and one each from the Mississippi Alluvial Plain and Gulf Coastal Plain. Wilson (1958) reported this species to be very uncommon in Mississippi, being collected from a roadside borrow-pit and a deep stream, neither of which had vegetation, but Froeschner (1962), while listing it, had no record of its occurrence. Arkansas specimens have been collected from a farm pond, pool areas of rivers or creeks and a lake. All collection sites contained turbid water; vegetation was present in all habitats except the lake. Hungerford (1933) reported this species to have been collected during the months of July-October. Wilson (1958) reported taking it in August and October. Arkansas specimens were taken during March, April and October-December.

Notonecta undulata (Say) was first reported from Arkansas by Hungerford (1933). It is a common and widespread species in Arkansas, being represented by 205 individuals in 54 collections from 23 counties throughout the five natural divisions of Arkansas (Fig. 6). The majority of the collections of this species have been taken from the eastern portion of the state. Hungerford (1933) thought this species to be "the most common species in the United States". This species is similar in size and color pattern to *N. indicia*, and therefore these two species are often confused for each other (Hungerford, 1933). Further, causing even greater confusion, these two species are often collected together in the same sample. Froeschner (1962) reported this species to be very common in Missouri. Conversely, Wilson (1958) listed this species but had no record of its occurrence in Mississippi. Missouri specimens were collected from ponds and quiet sections of rivers (Froeschner, 1962). Arkansas specimens have been taken from most aquatic habitats, including swimming pools. Missouri specimens of the species were collected from January to July (Froeschner, 1962). Hungerford (1933) reported collections of this species for every month of the year. Arkansas specimens of this species have been taken during all months except July.

From present knowledge, it is probable that all eight notonectid species can be collected during any month of the year in Arkansas. Most should be found in any of the state's ecoregions. *B. confusa* and *N. uhleri* may be restricted in their habitat preference, however. The former appears to prefer clear well-vegetated waters, whereas the latter prefers turbid water with mud substrates.

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EVALUATION OF PARTICULATE AIR FILTERS FOR INDOOR AIR CLEANING

Indoor Air Quality is a growing health concern. Efforts are currently being made to reduce pollutants and to prevent illnesses resulting from inhalation of allergens and pathogens at home and in the workplace. Without adequate air filtration in the heating, ventilation, and air conditioning (HVAC) system, air pollutants may distribute through the house or building, or the HVAC system may become a source of allergens and pathogens.

In this study several types of filter were evaluated for their effectiveness in removing airborne particles in the size range of 0.2 to 1.0 μm in diameter and for the energy requirements associated with the filtration. Tested were: (1) a pleated paper type filter, (2) a 7.5 cm thick, medium efficiency pleated electret filter, (3) a 15 cm thick, High Efficiency Particulate Air (HEPA) electret filter, and (4) a standard fiberglass HVAC filter. The electret filter material consists of fibers having a semi-permanent charge which enhances collection efficiency through electrostatic attraction of the aerosol particles. Each of the filters was about 0.37 m^2 in cross section with the actual filter surface area varying depending on the thickness and number of pleats.

The filter evaluation tests were performed in a single residence with a volume of about 360 m^3 and having a 'central' HVAC unit. The evaluation procedure was adapted from "Draft Standard AC-1" of the Association of Home Appliance Manufacturers (1985), which gives guidelines for evaluating portable room air cleaners. For each filter, measurements were made of the effective Clean Air Delivery Rate (CADR) and the energy consumption rate.

When tested using a closed loop, recirculating system as in this study, the CADR is defined as the product of the total air flow rate, the particulate collection efficiency of the filter and a factor for the inefficiency of mixing within the test volume. A high CADR is desirable, particularly when accompanied by low energy consumption.

To measure CADR a high concentration of smoke from burning incense was distributed throughout the house. An optical particle counter (Climet model CI-7400) was used to monitor the concentration of particles in the air near the inlet to the air circulation system. Concentrations of greater than 3×10^8 particles/m^3 were obtained for particles with diameters between 0.2 and 1.0 μm. After extinguishing the incense sticks, a filter was installed at the fan inlet and the particulate concentration was monitored continuously for a period of one hour or until the concentration dropped to less than 50% of its original value. The procedure was repeated for all the filters and then with no filter installed.

The change in particulate concentration was modeled as an exponential decay such that the concentration, C(t), at time t was given by

$$C(t) = C_i \exp(-K\ t),$$

where

Ci = initial concentration, and
K = decay constant.

A linear regression was used to determine the decay constants from the measurements. The CADR for the system with the filter in place was calculated by

$$CADR = V * (K_e - K_n),$$

where

V = volume of the test chamber,
Ke = decay constant with the filter in place,
Kn = natural decay constant with no filter in place.

Flow rate and Pressure Drop were measured with each filter and used to calculate the energy consumption rate, W, in watts.

$$W = 0.0166 * Q * \Delta P,$$

where

Q = volumetric flow rate in m^3/min,

and

ΔP = pressure drop across the filter in Pascal.

The Clean Air Delivery Rate and Energy Consumption Rate results are given in Table 1. The exponential decay model of particle concentration versus time for each filter is presented in Figure 1.

Table 1. Test results for the evaluated filters.

FILTER	FLOW (m^3/min)	ΔP (Pa)	CADR. (m^3/min)	POWER (W)
Standard Fiberglass	24.64	12.5	.058	5.10
Pleated Paper	23.93	21.3	4.09	8.43
3 inch Electret	24.07	40.0	12.89	15.96
6 inch Electret	19.54	137.5	14.04	44.54

General Notes

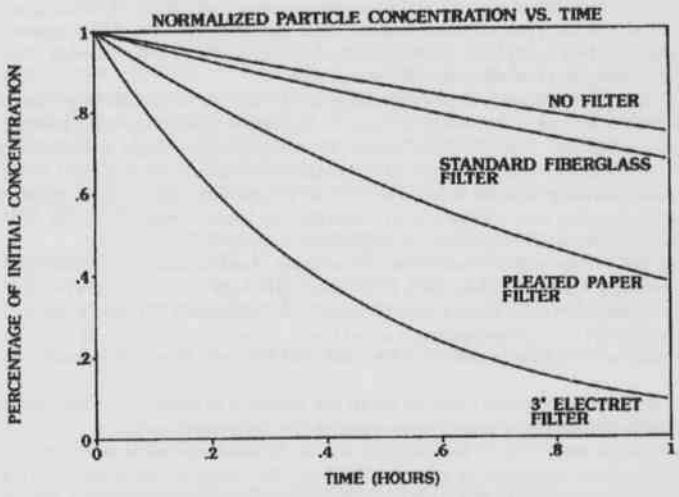

Figure 1. Best fit exponential decay of particulate concentrations with time in the test residence for each of the filters tested. The fit for the 15 cm electret filter is not shown as it fell nearly on top of that for the 7.5 cm electret filter.

The relative merits of each filter type are as follows:

(1) Pleated Paper Filter - This type demonstrated appreciable particulate removal ability in the submicrometer size range with moderate energy consumption.
(2) Electret Filters – The electret filters yielded the best small particle collection ability of those tested. The 7.5 cm electret gave 92% of the CADR of the 15 cm electret with only 36% of the energy consumption. The 15 cm electret loaded the blower, reducing the air flow rate resulting in a lower CADR than would otherwise have been expected.
(3) Standard Fiberglass Filter – The merits of this type include compatibility with existing HVAC systems and low cost. Small particle collection ability is minimal. Energy consumption is low.

The CADR numbers should be interpreted with caution. They are specific to the test aerosol and to the test chamber and air handling system. The CADR numbers for different filters can only be compared when all other factors in the determination of the numbers are the same. High CADR numbers are given by high filtration efficiencies. However, a maximum CADR exists which depends on the volumetric air flow rate and the mixing factor for the house. Therefore, continuing to increase the filtration efficiency will add little in terms of improved air quality but will increase energy consumption. Additional work in this study will be aimed at determining optimum filtration efficiency when both air quality and energy consumption are considered.

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THE VASCULAR FLORA OF PERRY COUNTY, ARKANSAS; A PROGRESS REPORT

Located in western, central Arkansas in the Ouachita Mountain Division, Perry County lies in the center of the Fourche Mountain Subdivision immediately below the Arkansas River Valley Subdivision of the Interior Highlands. The vascular flora of this county is poorly known; Perry County ranks at 56 of the 75 Arkansas counties for the number of known taxa (Smith, 1988. An atlas and annotated list of the vascular plants of Arkansas. Kinko's, 653 West Dickson Street, Fayetteville, AR. 72701). Community types represented in the County range from hydric sites (cypress swamps; ponds, streams and river banks) to bottomland hardwood forests, to pine forests, to upland hardwood forests, cedar glades and bluffs; included are disturbed sites ranging from hydric to xeric.

Numerous collection trips concentrated over the last year during the spring, summer and fall growing seasons have been made to sites representative of these community types. Currently 134 county records of vascular species have been identified. Voucher specimens are deposited in the herbaria of UCA and UARK. This current list is published with the Arkansas Native Plant Society as an Occasional Paper and may be obtained from Dr. James H. Peck, Biology Dept., University of Arkansas at Little Rock, 2801 S. University Ave., Little Rock, AR 72204.

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BACTEREMIA ASSOCIATED WITH MORTALITY IN AN ARKANSAS ALLIGATOR

Death from gram-negative septicemia has been reported several times in reptiles. In alligators this has been associated with populations that had been stressed due to changes in the natural or captive environment (Shotts *et al.*, 1972; Gordon *et al.*,1979). It is believed that the bacteria gain entrance to the blood stream of infected reptiles by natural or surgical wounds (Cooper, 1981). We report a case of death in an adult alligator associated with a septicemia or bacteremia in which the most prominent organism isolated was *Aeromonas hydrophila*. The alligator had been obtained from the wild but had been living isolated away from a natural or translocated population of alligators. The only significant pathology found on postmortem examination was minute hemorrhagic lesions in the gastrointestinal tract, which could have provided the bacteria entrance to the circulatory system.

A large, male alligator was captured on an embankment of a small, impounded lake on a geological elevation of the Mississippi delta known as Crowley's Ridge in East-Central Arkansas (St. Francis Co.) on March 10, 1985. The animal was known to have resided in the area for many years on this uplifted region, which is approximately 30 miles from the nearest known alligator population on the St. Francis River. The original territory and time of the alligator's arrival on Crowley's ridge are unknown. The alligator was 305-cm long (snout to tip of tail) and weighed 114-kg. The animal was recently deceased when captured and was immediately transported to the Arkansas State Livestock and Poultry Commission Laboratories in Little Rock for postmortem examination and collection of laboratory samples. The alligator had been seen alive the previous day and its heart muscle was still active when examined, therefore the time elapsed from death to postmortem examination was estimated to be less than12 hours. Aseptic culture specimens (3 samples each) were taken as follows: Aerobic and

anaerobic blood cultures from the cardiac chambers, aerobic and anaerobic cultures from liver tissue, aerobic and anaerobic cultures from swabs of the lung and trachea, and stool cultures. Standard clinical microbiology techniques were employed and the gram-negative isolates were identified with the API diagnostic panel (API products, Plainview, New York). Where possible, numbers of organisms isolated on agar plates were estimated on a scale of rare to 4+ (Bartlett *et al.*, 1978). Stool samples were also taken for ova and parasite examination by direct, concentrate, and trichrome staining techniques.

Prior to its death the alligator had been closely observed for a week. It was noted to be sluggish in its movements and it had noticeable bleeding from its nares. The only gross pathology seen on postmortem examination, in an otherwise healthy animal, were numerous small hemorrhagic lesions occurring intermittently throughout the gastrointestinal tract from the stomach to the small and large intestines. The intestinal lesions were small with a slight inflammatory response, and were not purulent. The lesions appeared to be confined to the mucosa and submucosa as there was no serosanguinous fluid in the peritoneal cavity. The bleeding from these lesions was apparently responsible for the nasal bleeding since the lungs and the bronchi were clear. In previous cases of gram-negative septicemia in crocodilians a nasal discharge has been associated with purulent pneumonia rather than with intestinal hemorrhaging (Shotts *et al.*, 1972). No tissue sections were taken for histopathology. There was little digestive residuum in the stomach and no evidence that the animal had recently fed.

The bacteriology results were as follows: Blood cultures (aerobic and anaerobic) – *Aeromonas hydrophila, Citrobacter freundii,* and *Clostridium bifermentans;* stool cultures – *A. hydrophila* (4+) and *Hafnia alvei* (2+); liver tissue (aerobic) – *A. hydrophila* (4+), *C. freundii* (3+), and *Enterococcus* (1+); liver tissue (anaerobic) – *Clostridium* spp., *Bacteroides* spp., and other nonidentifiable gram-negative rods; Lung swabs (aerobic) – *A. hydrophila* (3+) and a rare nonfermentative, nonidentifiable gram-negative rod; lung swabs (anaerobic) – *A. hydrophila* (2+), *Proprionibacterium acnes* (rare), *B. ureolyticus* (rare), *B. eggerthii* (rare); tracheal swabs (aerobic) – *Serratia plymuthica* (1+) and *Streptomyces* spp; tracheal swabs (anaerobic) – No growth. No evidence of animal parasites was found in the stool samples.

Gross examination of the intestinal tract and microscopic examination of intestinal scrappings failed to reveal the presence of helminths. Two placobdelled leeches were found in the oral cavity but no other ectoparasites were seen. Wright-stained blood smears were negative for erythrozoan parasites.

Conclusions from the laboratory examinations, necropsy, and field observations were that; 1) the alligator was an isolated individual from the wild which had no recent contact with other crocodilians, 2) it was not exposed to handling, physical trauma, or relatively high environmental temperatures, 3) it was a relatively healthy specimen presenting only with enteritis accompanied by minute hemorrhaging, and 4) it had either a bacteremia or septicemia with *A. hydrophila* being the predominant organism.

Aeromonas hydrophila is a motile, nonsporulating gram-negative bacillus ubiquitous in nature, especially in aquatic environments. It is so easily and frequently isolated from crocodilians and other reptiles that it has been considered to be either normal flora or a common transient (Gordon *et al.*, 1979; Flandry *et al.*, 1989). It has even been isolated from the tissues of healthy alligators (Gordon *et al.*, 1979). Under certain conditions *A. hydrophila* is believed capable of producing disease, presumably because of excessive environmental stress, physical handling, trauma, and immunosuppression (Cooper, 1981). The frequency and quantity of *A. hydrophila* isolated from all of the cultures (with the exception of the trachea) in the present case, strongly suggests this organism as the cause of a septicemia in the alligator. Probable cause of death can be hypothesized as associated septic shock. The lack of severe accompanying pathology is not inconsistent with cases of presumed septic shock in reptiles (Cooper, 1981).

The variety of organisms isolated suggests that the time lapse before the cultures were taken could have allowed the multiplication of *A. hydrophila* and the other identified microbial agents. It is possible that these agents could have gained entrance to the circulation after death. However, similar polymicrobic septicemias are seen with humans, especially in patients that are immunocompromised.

Although *A. hydrophila* can be isolated from the gastrointestinal tract in asymptomatic animals, its predominance in the stool samples in the present case suggests that this organism may have also produced the initial enteritis. Enteritis is not an uncommon finding with infections of *A. hydrophila* in both reptiles and humans (Marcus, 1981; Zwadyk, 1988), but it is difficult to be certain as to whether the initial lesions were produced by *A. hydrophila* or if the lesions were even of bacterial origin. Other gram-negative bacteremias of crocodilians, not involving *A. hydrophila,* have been attributed to having their origins in skin abscesses from puncture wounds (Novak and Seigel, 1986; Heard *et al.*,1988). Since *A. hydrophila* was isolated from intestinal samples in large numbers, entrance by this bacterium to the blood stream, in any case, would most likely have occurred through the intestine.

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General Notes

HYPERINFESTATATION OF SMALLMOUTH BASS *(MICROPTERUS DOLOMIEUI)* BY THE TREMATODE *CLINOSTOMUM MARGINATUM*

Over 500 black bass from Crooked Creek, an Ozark stream in North Central Arkansas (Marion Co.), were necropsied and examined for *Clinostomum marginatum* metacercariae during the late spring, summer, and early fall seasons of 1988-1990. In this survey three smallmouth bass, collected in the late summer of 1990, were found to have individual parasite intensities greater than the heaviest previously recorded. The number of metacercariae found and the standard length (cm) of the hosts were 2500, 24.2; 852, 15.2; and 627, 15.2. All three bass were taken from near the juncture of Crooked Creek and the White River. Previously the largest number of *C. marginatum* reported from fish hosts were 500 from a bullhead *(Ictalurus nebulosus)* in Pennsylvania (Torres and Price, Tenn. Acad. Sci. 46:131, 1971), 325 and 191 found in yellow perch *(Perca flavescens)* from Lake Oneida, New York (Van cleave and Mueller, Roosevelt Wildlife Annals 3:230, 1934). Another heavy infection of 230 metacercariae was reported in a spotted bass *(Micropterus punctulatus)* from Missouri (Taber, Prog. Fish-Cult. 34:119, 1972).

Other heavily infected smallmouth bass collected from Crooked Creek in 1977 and 1987 (Daly *et al.*, Proc. Ark. Acad. Sci. 41:29, 1987) and in 1988-90, wre found to have 324, 282, 179, 144, 143, 126, 112, 105, and 101 metacerariae, respectively. The most severe pathology produced by *C. marginatum* was found in the smallmouth bass that had 627 parasites. Damage to the fish was similar to that reported on the Pennsylvanian bullhead where metacercariae were similarly being extruded externally through perforations in the weakened abdominal wall.

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OBSERVATIONS ON A RESIDENT POPULATION OF *MYOTIS LUCIFUGUS*, IN JACKSON COUNTY, ARKANSAS

The little brown bat *(Myotis lucifugus)* is one of the three most common bat species found to infest man-made structures in North America. The other species are the big brown bat *(Eptesicus fuscus)* and the Brazilian free-tailed bat *(Tadarida brasiliensis)*. These three bat species are commonly referred to as "house bats" by the pest control industry. The destruction of roosting sites and the indiscriminate use of pesticides are believed to adversely affect these species.

The little brown bat, *M. lucifugus*, is typically considered to be a northern bat species (Davis, *et al.*, Am. Midl. Nat. 73(1):161-165, 1965). However, it has been reported as far south as Oklahoma, Louisiana, and Arkansas. *M. lucifugus* has been reported to be widely distributed in Missouri (Schwartz and Schwartz, The wild mammals of Missouri. pp. 53-62, 1981), but is seldom reported in central or southern Arkansas (Saugey, *et al.*, Proc. Ark. Acad. Sci. 43:71-77, 1989). This species is known to use barns, sheds, attics, and other man-made structures as maternity colonies and hibernacula.

Observations contained herein are based on resident colonies of *M. lucifugus* in Jackson County, Arkansas. The initiation of this study was prompted by the preliminary efficacy testing of Varpel Rope™, a purported bat repellent. These findings are in support of and in conjunction with the registration of this product with the Environmental Protection Agency.

The colonies were located in the attics of privately owned residences (Sites 1 and 2) in Jackson County, Arkansas. Observations were taken from visits conducted from July 9, 1990, to January 8, 1991. Large numbers of bats have occupied these buildings for several years as evidenced by the large volume of guano covering the floor of the attics. The depth of the guano ranged from 3 cm to over 38 cm, with the average depth approximately 8 cm. It was also apparent that several unsuccessful attempts had been made to eliminate the colonies, resulting in the deaths of numerous bats.

On July 9, 1990, approximately 300-500 bats were observed in the attic of Site 1, and approximately 500 bats were in the attic of Site 2. It was also noted that due to the weight of the guano, the ceilings of the structures were collapsing in some sections. On July 18, 1990, the sites were revisited to further assess the extent of the infestation. Several hundred *M. lucifugus* were observed in the attics of both structures. On August 24, 1990, the size of the colony in Site 1 was estimated at 200 individuals. The bats remained inactive until after 10:30 pm, when they left the building individually. On August 25, 1990, the colony at Site 1 was estimated to contain 300-500 bats.

On September 6, 1990, a modified funnel trap was constructed at Site 2, at 5:45 pm. Bats began to exit the structure at 7:45 pm and trapping continued until 9:15 pm. The bats were counted, identified, and then released at the site. Five hundred *M. lucifugus* were trapped with additional bats observed leaving the structure after the trap had been disassembled.

Following the removal of the trap, approximately 53 meters of Varpel Rope™ was placed in the attic of Site 2. The openings in the structure were left open to allow access to the house by the bats.

On September 11, 1990, the access point of the structure was observed and only seven bats were seen to exit the structure. A visit inside the structure confirmed that no additional bats remained in the attic and that the product still retained the repellent qualities.

On September 13, 1990, the trap was reassembled at 7:00 pm and trapping continued until 9:30 pm. Thirty-one *M. lucifugus* were trapped with additional bats observed leaving the structure after the trap had been disassembled. The Varpel Rope™ was apparently no longer effective and the access points were sealed to prevent reinfestation.

On November 1, 1990, the size of the colony, at Site 1 was estimated to contain 50 *M. lucifugus*. Skulls were removed from the attic floor and 49 adult *M. lucifugus*, 15 juvenile *M. lucifugus* and one adult *Nycticeius humeralis* were found. On November 9, 1990, the size of the colony, at Site 1 was estimated to contain 20 *M. lucifugus*. Additional adult (23) and juvenile (12) *M. lucifugus* skulls were collected. Subsequent visits on December 23 and January 8, 1991 revealed no bats.

M. lucifugus generally disperse from the summer roosts by October each year (Humphrey and Cope, Population ecology of the little brown bat, *M. lucifugus*, in Indiana and North-Central Kentucky. p. 1-2, 1976). The above observations demonstrated that the bats were still inhabiting Site 1 well past the normal autumn swarming times.

Voucher specimens were retained as necessary and are deposited in the Collection of Recent Mammals at Arkansas State University Museum of Zoology.

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LIGHTNING: A COMPLEX NATURAL PHENOMENON THAT DEFIES SIMPLE ANALYSIS

Hauksbee (1706/7) was the first to recognize the similarities between lightning and laboratory sparks produced in a partial vacuum. Having been produced in ideal conditions, including idealized geometrical settings, the analysis of laboratory sparks is not as treacherous as that of actual lightning. The study of lightning remained in its primitive stages for almost two centuries, awaiting the discovery of the electron, the main element in the propagation of breakdown waves. Accurate measurements of the speed and structure of breakdown waves awaited the development of modern electronic devices with sufficiently rapid rise-times. The complexity of the investigation of lightning partly lies in the imperfectly understood phenomena of electrical charge development and distribution. Theoretical analysis of the phenomena involves analysis of complex factors including ionization of the upper atmosphere by cosmic rays, formation of space charges and propagation of shock waves driven by electron gas pressure. The behavior of the phenomenon is best explained by fluid dynamic equations coupled with Maxwell's equations. This paper will address the formation and propagation of lightning. Theoretical developments will also be discussed.

BACKGROUND

The 1920's could be marked as the era of progress in laboratory and field observations and the beginning of a search for a theoretical analysis of breakdown waves. Following extensive research on the formation and propagation of space charge using a discharge tube with a potential gradient across it, Beams (1930) called these waves "potential waves". He theorized that electrons are the main element in wave propagation. This is consistent with the observed total lack of heavy particle motion. He proposed that near the electrode to which a high potential is applied the electric field is very intense and extensive ionization should take place. Due to the large differences in mass and resultant mobility between positive ions and electrons, a space charge will be created following initial ionization. Near the high potential electrode, the electric field is very large. This large electric field accelerates free electrons causing further ionization and extension of the high potential conducting region. Being a conductor, the ionized gas can not maintain an internal electric field. Therefore the electrode's potential will dictate the potential of the ionized region. Maximal electric field intensity was considered to exist at the interface between the neutral gas and the ionized region. The intense electric field and electron gas pressure were hypothesized as the main causes of wave propagation. Beams (1930) reported a speed of 4×10^9 cm/sec for breakdown waves inside a tube 490 cm in length and 5 mm in diameter for air at pressures ranging from 0.04 to 0.5 mm of mercury.

Schonland and Collens (1934) made extensive observations of lightning in South Africa using the Boys (1926) rotating lens camera. They reported that a lightning stroke from cloud to ground starts with a "leader stroke", followed by a return stroke that advances up the center of the leader stroke to the cloud.

The leader stroke, which are not as bright as the return strokes, can have diameters as large as 10 m. This is a factor of 10^2 larger than the diameter of the return strokes. The leader strokes, after advancing for about 50 meters, pauses for approximately 50 μsec, before it takes another step. It advances toward the ground in a series of such steps, leaving behind a highly conducting path. The return stroke, which is the brightest and highest current part of the discharge, produces a large amount of heat. The sudden appearance of such a large amount of heat causes the rapid expansion of the air, resulting in the familiar thunder clap.

A few hundredths of a second after the return stroke disappears, if the electric field in the region has not been reduced below the breakdown initiation level, another leader will come down the column. This leader, because of its bright leading edge, is called a "dart leader". It propagates along the entire column in a single step. The dart leader will be followed by another return stroke. Using this pattern, lightning can strike as many as ten times on the same channel. At some points along the tracks, the leader stroke may branch and develop into two separate steps. The return stroke will then advance along the path of the branch that touches the ground first.

Schonland and Collens's (1934) measurements yielded speeds as high as 3×10^9 cm/sec for the luminous tip of the "leader", and speeds of up to 10^{10} cm/sec for the return stroke. They suggested that electrons in the wave front travel at these high speeds.

In a separate analysis, Schonland *et. al.* (1938) placed the stepped leaders into two categories, α and β. Compared to the β type leader, α type leaders near the cloud are low in luminosity, shorter in length, straight, rarely branched, and slow moving. However, near the ground a β type leader will have the characteristics of the α type leader.

Using Townsend's (1914) α values (the number of ions in the field direction per centimeter of path created by one electron), Cravath and Loeb (1935) calculated a lower limit for the field required by electrons traveling at 10^9 cm/sec. They reported the required electric field to be in excess of 4×10^6 V/cm. However, such high electric fields had never been observed. The velocity of electrons at the wave front therefore had to be far lower than the speed of wave propagation. Based on reasonable assumptions for the conditions existing in lightning, Cravath and Loeb (1935) showed that a field of 10^5 V/cm would account for the existence of electrons in the gas ahead of the lightning stroke and cause the wave to propagate at 10^9 cm/sec through collision induced ionization. According to Townsend (1914) the electron velocity at the wave front where the field is 10^5 V/cm is 3×10^7 cm/sec. Using charge conservation Cravath and Loeb (1935) calculated a 200 A current in the channel, based on charge distribution and propagation speed. The number of electrons traveling at 3×10^7 cm/sec required for a current of 200 A is $n = 4 \times 10^{13}$/cm. They showed that the above mentioned field and an assumed channel radius of 1 cm would produce the necessary number of electrons to propagate the stroke with a velocity of 10^9 cm/sec.

By allowing lightning discharges to pass through a fiberglass screen, Uman (1964) was able to measure the diameter of lightning strokes. In 1944 Bruce (1944) suggested that the lightning stroke consists of a hot inner core, surrounded by corona. Uman (1964) accepted this suggestion and he considers the diameter of the lightning stroke to be the diameter of the inner core. Uman's (1964) measurements of the diameter with fiberglass resulted in six holes with diameters between 2 cm and 3.5 cm, and six holes with diameters between 2mm and 5 mm. Schonland has reported lightning diameters as high as 16 cm.

In 1970 Uman and Mclain (1970a) derived equations allowing him to calculate the current in a lightning return stroke from a measurement of either the magnetic flux density or the radiation field (electric or magnetic) of the discharge. In deriving these equations, he treated the channel as if it were composed of a circular arc above the earth with its "image" arc below the earth's surface. Uman and Mclain (1970b), considering a section of a stepped leader channel to be an idealized straight vertical line (about 50 m) above a perfectly conducting plane (the earth), derived expressions relating the stepped leader radiation field to the leader current and current propagation velocity. For typical values (channel section length = 50 m, velocity = 8×10^7 m/sec, and peak current = 20 Ka/μsec), his computed maximum rate of change in leader current for a model type α leader was 2 Ka/μsec, while it was 10 Ka/μsec for a model type β leader.

Berger (1966) and co-workers have made extensive measurements of the lightning return stroke currents at the tops of two, 55 m towers atop Mt. San Salvadore in Lugano, Switzerland. They measured induced voltages in resistive shunts caused by lightning strokes. Such measured induced voltages allowed them to calculate lightning return stroke currents.

The data (average) on the process of lightning breakdown waves have been adopted from the above mentioned references and works of Uman (1987) and Fowler (1982). The data are compiled in Table 1.

General Notes

Table 1. Average data on the process of lightning strokes. Adopted from the works of Uman (1987) and Fowler (1982).

Breakdown Field in Dry Air	2.5×10^6 V/m
Cloud Potentials (1 Km Cloud Radius)	$\approx 2 \times 10^9$ V
Cloud Charge (1 Km)	$\approx 10^3$ Coul
Cloud Dissociated Charges (1 Km)	$\approx 10^6$ Coul
Velocity of Pilot Leader	3×10^5 m/sec
Diameter of Pilot Leader	5 m
Length of Leader Steps	50 m
Velocity of Step Leaders	$2 \times 10^6 - 5 \times 10^7$ m/sec
Diameter of Step Leaders	2 m
Current in Step Leaders	5×10^2; 3×10^3 Amp
Return Stroke Velocities	$1.5 \times 10^7 - 1.5 \times 10^8$ m/sec
Return Stroke Currents	10 - 100 K Amp
Return Stroke Diameters	0.5 - 15 cm
Return Stroke Temperatures	25000 °K
Single Stroke Charge Transport	1 - 5 Coul
M-Stroke Charge Transport	0.01 - 0.1 Coul
Dart Leader Velocities	$1.2 \pm 0.3 \times 10^7$ m/sec
Dart Leader Diameters	0.3 - 1.5 m

MODELS

To rationalize his experimental data, Cravath (1934) suggested that breakdown wave propagation could result from photo-ionization. Following Cravath's suggestion, Schonland (1956) derived an approximate relation for the speed of the advancing ionization front. His theoretical values for the speed of the ionization front were in fair agreement with the earlier observations of dart leader speeds. Along with several other explanations for their experimental results, Loeb (1965) proposed a qualitative model for breakdown of a gas on the basis of photo-ionization. In this model, emitted photons from the excited atoms excite and ionize neutral particles in front of the wave. The newly excited particles in turn emit photons which continue the process.

The theoretical analysis of lightning discharge took a great leap in the 1960's with a theory advanced by Paxton and Fowler (1962). Their theory is based on electron impact ionization in an electric field as opposed to photoionization. They noted that the potential breakdown of gases is a fluid dynamical phenomenon, being of the nature of electron shock waves. They suggested that, near the electrode where the potential gradient in the gas is greatest, a small quantity of gas will be ionized. The resulting electrons will acquire kinetic energy from the external electric field. This high-temperature electron gas expands rapidly, producing an electron shock wave. The electron shock wave propagates through the gas, partially ionizing the neutral gas molecules. The external electric field provides energy to the electrons, which create the shock front, and is therefore the driving agent for wave propagation. A three-fluid hydrodynamical model was applied to a quasi-steady state, three-component system.

Earlier, Burgers (1964) proposed a model similar to that of Paxton's, and developed a set of equations nearly identical to those of Paxton and Fowler (1962). A model based on the application of fluid dynamic equations presents considerable mathematical difficulty.

ANALYSIS

Shelton and Fowler (1968, 1974) extended the theory of Paxton and Fowler (1962). They suggested that, even though neutral particles and positive ions have small velocities in comparison to electrons, due to their large masses, their momentum and energy changes can not be neglected. In their opinion the name "Electron Fluid-Dynamical Wave" (EFDW) most fully describes the phenomenon. They were able to write three-fluid, hydrodynamical equations for electrons, neutral atoms, and positive ions, which account for the equations of mass, momentum and energy conservation. The equations of conservation of mass, momentum, and energy, coupled with Poisson's equation comprise the set of Electron Fluid-Dynamical equations. Using the principle of frame invariance, and considering the atom as a hard sphere at rest in the laboratory frame, they were able to derive expressions for the momentum and energy transferred in elastic and inelastic collisions between electrons and heavy particles. Using the assumption that a strong (shock) discontinuity exists at the leading edge of the wave, and equations for conservation of total momentum and energy, they found a set of boundary conditions at the wave onset. Using these boundary conditions they were able to solve the electron fluid-dynamical equations across the shock zone employing approximation methods. Their approximate solutions to the set of EFD equations for pro-force waves (waves moving in the direction of the electric field force), met the expected boundary conditions at the trailing edge of the wave reasonably well. In order to solve the EFD equations, Shelton (1968) had to neglect terms involving heat conduction and the heat loss by electrons to heavy particles in elastic collision. Shelton's (1968) boundary conditions on electron velocity (v) and electron temperature (T_e) at the wave front led him to enforce a minimum wave velocity condition on these shock discontinuity solutions ($1/2mV_o^2 \geq e\phi$). The symbols m, e, V and ϕ denote electron mass, electron charge, wave velocity, and ionization potential respectively.

The shock zone is composed of two regions: a thin dynamical Debye sheath region, followed by a relatively broad Quasi-Neutral region (QNR). In the sheath region, the electric field starting from E_o (the electric field ahead of the wave) decreases to zero and the electrons come to rest relative to the heavy particles. In the QNR the electrons come to thermal equilibrium with heavy particles by further ionizing the gas.

In searching for precise solutions, Fowler *et al.* (1984) used a computer (IBM3081 Model D=5 MIPS) in attempts to integrate the set of EFD equations through the sheath region. All our attempts at integrating the set of equations, by inclusion of terms neglected by Shelton in energy equation, failed to meet the expected boundary conditions at the end of the sheath region. We finally abandoned the requirement that the temperature derivative must be zero at the wave front. This is acceptable because, in a shock discontinuity, variables may have derivative as well as value discontinuities at the shock front. In final form, our EFD equations, equations of conservation of mass, momentum, and energy, and Poisson's equation respectively are:

$$\frac{d(v\psi)}{d\xi} = \kappa\mu v,$$

$$\frac{d}{d\xi}\left[v\psi(\psi-1)+\alpha v\theta\right] = -v\eta - \kappa v(\psi-1),$$

$$\frac{d}{d\xi}\left(v\psi(\psi-1)^2+\alpha v\theta(5\psi-2)+\alpha v\psi+\alpha\eta^2-\frac{5\alpha^2 v\theta}{\kappa}\frac{d\theta}{d\xi}\right) = -\omega\kappa v[3\alpha\theta+(\psi-1)^2],$$

$$\frac{d\eta}{d\xi} = \frac{v}{\alpha}(\psi-1).$$

These equations have been nondimensionalized, by introducing dimensionless variables,

$$E = \eta E_0, \quad n = \frac{\epsilon_0 E_0^2}{2e\phi} v, \quad v = V\psi, \quad T_e = \frac{2e\phi}{k}\theta,$$

$$x = \frac{mV^2}{eE_0}\xi, \quad \alpha = \frac{2e\phi}{mV^2}, \quad \kappa = \frac{mV}{eE_0}K, \quad \mu = \frac{\beta}{K}, \quad \omega = \frac{2m}{M}.$$

The dimensionless variables v, ψ, θ, η, ξ, are respectively, electron concentration n, electron velocity v, electron temperature T_e, electric field E, and position x in the wave profile. The symbols κ and β represent the elastic collision frequency and ionization frequency. The ionization rate, μ, was calculated by an involved expression derived by Fowler (1983), which includes nonequilibrium aspects of the distribution function.

$$\mu = \mu_0 \int_A^\infty \sigma_i x^2\, dx \int_B^\infty \frac{e^{-(x-u)^2} - e^{-(x+u)^2}}{u}\, du\, e^{-2Cu},$$

where $A^2 = 1/2\theta$, $B = (1-\psi)A/\alpha^{1/2}$, and $c = k\alpha^{1/2}/A$.

Acceptance of the temperature derivative discontinuity at the shock front altered the form of the shock conditions, and the new set of boundary conditions in terms of nondimensionalized variables is:

$$\eta_1 = 1; \quad \alpha\theta_1 = \psi_1(1-\psi_1),$$

$$\psi_1 = \frac{5(1+\alpha\theta_1'/\kappa) - [(3-5\alpha\theta_1'/\kappa)^2 + 16\alpha]^{1/2}}{8};$$

$$v_1 \neq 0.$$

Using the complete set of EFD equations, coupled with our set of boundary conditions, allowed integration of the EFD equations through the sheath region. The solutions met the boundary conditions at the end of the sheath ($\psi_2 = 1, \eta_2 = 0, \eta'_2 = 0$) within the accuracy of the integration step.
Fowler (1976) divided the breakdown waves into three categories:

Class I waves; waves moving into a medium of zero electron concentration.
Class II waves; waves moving into a medium of high electron concentration.
Class IIIwaves; waves which did not fulfill zero current condition (1968) (return stroke in lightning).

Hemmati and Fowler (1985) were able to solve the EFD equations inside the sheath region, for both proforce waves and antiforce waves, for all three categories of waves. The solutions conform with the boundary conditions at the end of the sheath. The acceptance of the temperature derivative discontinuity at the shock front allowed a lower range of electron drift velocities which have been observed experimentally. In Fig. 1 Fowler *et al.* (1984) values found for κ are plotted as a function of wave velocity. Our results compare well with the experimental data collected by Scott and Fowler (1977).

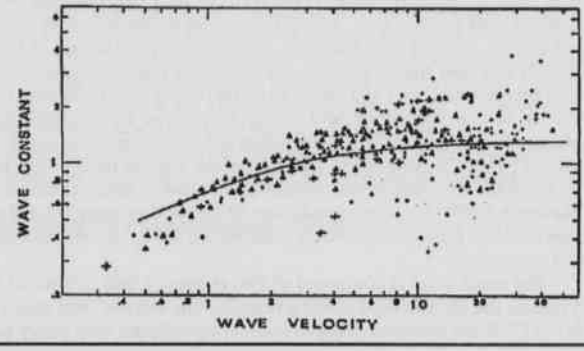

Figure 1. Wave speed data for argon (triangles), nitrogen (dots) and helium (crosses) reduced to a common estimate of wave speed constant K for ordinates versus $1/\sqrt{\alpha}$ for comparison with theory.

General Notes

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A DATA ACQUISITION AND CONTROL PROGRAM FOR CHROMATOGRAPHY

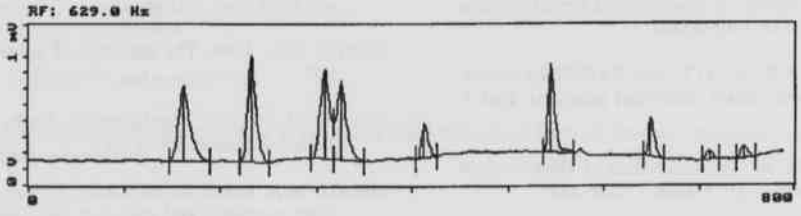
The recent availability of computers and microprocessors has allowed for considerable improvement in data acquisition and processing from instrumentation. In the last fifteen years, all types of laboratory instruments have been computerized. Initially, dedicated microprocessors were used to control various instrument functions. These early attempts rarely utilized actual data acquisition, normally relying on chart recorders and other data displays common even earlier. However, with the wide availability of more sophisticated microprocessors in the last decade, devices designed to control and acquire data for storage in digital form appeared in the literature and as commercially available systems. Such systems are commonly used with FT-IR spectrometers, mass spectrometers, and gas and liquid chromatographs.

Many instruments available today are the product of recent advances in technology, and represent an evolutionary path which brings together the best components from past and present instrumentation. One such instrument which has recently become available is the Ithaco Model 3981 PC Board Lock-In-Amplifier (Model 3981 Operations Manual, 1989, Ithaco, Ithaca, NY). The 3981 mounts all circuitry onto an IBMPC-AT compatible board which uses the AT bus for all power and data storage needs. This allowed the 3981 to be powerful and have a number of features while being available at low cost. While many instrumental techniques make use of lock-in-amplification, it is of major importance in the field of infrared (IR) spectroscopy due to the inherent noise characteristics of many IR measurements. Many applications in our laboratory are IR spectroscopy based, such as flame infrared emission chromatographic studies, IR emission studies of flames and furnace emissions, and rocket plume IR emissions. While the 3981 LIA worked well with our applications, we found that we needed more advanced software to control, acquire, store, and process data from various experiments. This software had to be generally applicable to all of our projects, rater than be specifically designed for only one application. Having previously written software for a variety of other instruments, including an external LIA (Hudson, Henson, and Hood, Proc. Ark. Acad. Sci., 44:67-70, 1990), the "C" programming language was chosen due to its versatility and speed. Fig. 1 shows data typical of that collected when the LIA and software are used as a FIRE chromatographic data station.

Figure 1. FIRE chromatographic data, emission vs. time.

The 3981 LIA was built to allow the use of up to four separate 3981s in any one computer system. One project of interest to us involves monitoring the IR emissions from two different infrared emission bands, in order to analyze for two elements simultaneously. The use of two IR detectors necessitates two LIAs and software channels to acquire and process the signal. This dual channel feature has been included in the program, and allows the program to be toggled between a one and two board mode. While in the two board mode, data collection is synchronized and data is displayed on the computer screen simultaneously for both channels, in real time. Each channel can be printed, time or intensity scale expanded, or further processing undertaken independently.

After the data have been collected, the software can process the data, automatically finding the location of and the area under the peaks. Fig. 2 shows the previous data after processing for peak location and marked for integration, along with a printed report. The location time of the start and end of a peak is based on the slope of the tangent at each data point. The tangents are approximated by a moving least squares fit of a straight line to segments of the data. The number of data points is user selectable, allowing the use of more points to eliminate noise effects. Integration was accomplished using the trapezoidal rule, as opposed to Simpson's Rule in the previous MBasic program (Hudson, Henson, and Hood, Proc. Ark. Acad. Sci., 44:67-70, 1990). This approach is functionally very similar to that used by commercial chromatographic integrator units, and is comparable in computational time required and equality of results.



Mon Mar 25 09:42:19 1991

Number of samples: 790 Time between samples: 0.10 sec

LIA sensitivity: 1 mV LIA time constant: 333. ms

Reference frequency: 629.0 Hz

Peaks between sample #0 and sample #789: 9

Peak #	Area	Height	Location	Start	End
1	0.0064615	0.00047038	162	148	190
2	0.0065129	0.00065827	233	221	252
3	0.006411	0.00055543	309	295	318
4	0.0057237	0.00048632	326	319	350
5	0.0016025	0.00021317	414	406	427
6	0.0043248	0.00054748	546	537	569
7	0.0016383	0.00023639	650	643	664
8	0.00042138	5.4549E-005	712	705	722
9	0.0006518	7.5709E-005	748	741	760

Figure 2: Processed FIRE chromatographic data showing peak location and integration marking with printed report.

The program offers the user of an Ithaco 3981 LIA a great deal of versatility in acquiring, processing, and storing data. Using the PC bus for data transfer instead of an RS-232 serial line, as is common in other LIAS and associated control programs, allows more speed and greater reliability. Also, the combination of PC, 3981 board level LIA, and this software is economical and easy to use. Those interested in this software should contact the authors.

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General Notes

IDENTIFYING *COLIBRI* HUMMINGBIRDS OCCURRING IN ARKANSAS USING INDIRECT MEASUREMENTS

The Green Violet-ear *(Colibri thalassinus)*, a Latin American hummingbird, is extremely rare north of Mexico (Amer. Ornithologists' Union. 1983. Check-list of North American Birds, Wash., D.C.). The surprising first Arkansas record of the species occurred at Fort Smith, Sebastian County, where it was photographed (2 x 2 inches color transparency) at a hummingbird feeder by William B. Brazelton on 16 September 1984 (erroneously dated 7 October in James and Neal. 1986. Arkansas Birds: Their Distribution and Abundance. Univ. Arkansas Press). The photograph showed definitely that the large hummingbird pictured was in the genus *Colibri*, but the image was not decisive in determining whether the bird was a Green Violet-ear or the larger Sparkling Violet-ear *(C. coruscans)*. Although the chances of it being a Sparkling Violet-ear were negligible, because that species has never been found north of Colombia, South America (Peters. 1945. Check-list of Birds of the World, Vol. 5. Harvard Univ. Press), there was still this possibility based on the fact that the critical plumage characteristics were not obvious in the photograph. Stephen W. Cardiff of Louisiana State University recommended that I attempt to determine the beak length, which is diagnostic, by measuring the bill on the photographic transparency for comparison to the measured dimensions of the hummingbird feeder in the same photograph.

The measurements were made by viewing the diffusely backlighted transparency on the stage of a 15x binocular dissecting microscope. A fine-scale comparator (scale in 0.1 mm divisions) was superimposed on the photograph visible through the microscope. Thus the bird's beak length and feeder dimensions were read directly in the units of the comparator scale. Knowing the actual feeder measurements (using a dial caliper), the bill length in millimeters was calculated from a formula based on simple proportions: $l=mx/y$, where l is the actual bill length in millimeters, m and y are bill length and feeder dimensions respectively expressed in comparator scale units, and x is the actual feeder dimension in millimeters. The known variables m, x, and y are used to solve for bill length. In doing this it is essential to use a photograph that shows the bird exactly in profile, which with hovering hummingbirds at feeders is not at all difficult to obtain.

Using the photograph of the Fort Smith bird as an example; on the transparency the bill (m) was 12.23 units, the feeder dimension used (y) was 29 units, compared to the actual feeder measurement (x) of 39 mm. Thus solving for $l=12.33 \times 39/29=16.58$ mm, the beak length equaled 16.58 mm. This length beak is definitely at the low end of bill lengths for the smaller species, the Green Violet-ear. Cardiff supplied bill measurements of both species from the Louisiana State University collection as follows: Green Violet-ear (13 specimens) range from 17.8 to 20.2 mm, mean 19.1 mm; Sparkling Violet-ear (10 specimens) range 21.7 to 24.2 mm, mean 23.2 mm. Notice that there is no overlap in the range of bill lengths for the larger Sparkling Violet-ear compared to the smaller Green Violet-ear. This non-overlapping separation is confirmed by Ridgeway (1911. The Birds of North and Middle America. U.S. National Museum, Bull. No. 50, Smithsonian Inst.).

Care has to be exercised to measure only the exposed culmen length (cord) in the bird profiles, which is the length of the beak from where the feathers end a short way down the bill, measured from there to the tip. This feather terminus is marked by a point where the plumage of the forehead tapers down and ends at the maxilla. Having a hummingbird specimen of any species on hand helps as a reference in finding this spot on the photograph.

Subsequently to the Fort Smith bird, which was there only from 4 to 5 days to about 17 September 1984, there have been three additional occurrences of Green Violet-ears in Arkansas. One was in Arkadelphia in Clark County, 2-4 June 1989, another occurred in Newton County between Lurton and Cowell, 6-23 July 1990, and the final one was at Rogers in Benton County from 4 August to 5 September 1990. All three were photographed, bill lengths determined, and all thereby proved to be Green Violet-ears.

The Arkadelphia bird photographed by Don Harrington had the longest bill of the four records, measuring 19.18 mm. Two transparencies of the Newton County bird were used, both photographs taken by Sue Burlingame. This provided an opportunity to test repeatability of measurements between slides. In addition, three different feeder dimensions were used separately to verify the technique. Two of the feeder dimensions produced a bill length of 18.3 mm in both photographs. The other dimension showed bill length of 19.25 mm, also in both photographs. This shows the variation in accuracy that can be expressed using the technique. The one millimeter difference would not have been decisive in obscuring the identity of any of the four birds.

The beak length of the bird at Rogers, Arkansas, was measured from one photograph taken by me, and from two photographs taken by Max Parker, using the same feeder dimension measured separately in each of three transparencies. In all three cases the bill proved to be 16.7 mm long. This is excellent documentation of how precise the measurement technique can be.

The Rogers bird was 60 miles northwest of the Newton County site, and arrived shortly after the Newton County bird disappeared. This led to speculation that the two records could have been of the same individual, which was discounted when the bill length of the Rogers bird proved to be over 1.5 mm shorter than in the Newton County bird. Besides bill length, several kinds of evidence suggested conclusively that the two birds were different individuals. These were as follows, 1) there was a narrow blue band on the nape of both birds, which appeared to be much wider (1.5 mm) and brighter blue in the Rogers bird than in the Newton County bird (1.0 mm), 2) the blue mask was more conspicuous and wider posteriorly in the Rogers bird, 3) the Rogers bird had a dingy brown color on the forehead and anterior crown that was not iridescent whereas the Newton County bird was iridescent green in sunlight over the whole crown and forehead, appearing black not brownish in dimmer light, 4) the Newton County bird had a tiny white spot over the left eye that was not present in the Rogers bird (although this could have been a temporary blemish), 5) in behavior the Rogers bird was bold and would appear at the feeder even when people were in the yard nearby, whereas the Newton County bird was very shy and usually did not appear when people were in the yard, and finally 6) while the Rogers bird seldom vocalized the Newton County bird was very noisy, frequently making "chip" notes, and often perched and emitted the principal song of the species.

A big debt of gratitude is owed to those who persisted in finding whom to contact about the "strange large all dark hummingbird" at their feeder. The presence of the Green Violet-ear in Arkansas would not have been known without these efforts from Blanche Tinder, Jane Bowden, Sue Burlingame, and Patty Simmons. (The hummingbird photographs and associated documenting materials have been deposited in the file of Arkansas bird records maintained by the Arkansas Audubon Society.)

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RANGE EXTENSION OF THE ENDANGERED GRAY BAT, *MYOTIS GRISESCENS*, INTO THE ARKANSAS RIVER VALLEY

The Arkansas distribution of the endangered gray bat, *Myotis grisescens*, has typically been associated with the cave region of the northern Ozark Mountains comprising the Salem and Springfield Plateaus (Harvey *et al.*, 1981; Sealander and Heidt, 1990). On 25 October 1990, one of us (TAN) visited Land's End Cave, a sandstone fracture cave located in Pope County (T7N-R21W-S13), to investigate reports the cave contained large numbers of bats (Fig. 1).

Figure 1. Arkansas distribution of the endangered gray bat, *Myotis grisescens*. Back-slashed area represents geographic range according to Sealander and Heidt (1990). The closed circle indicates the new record extending the range southward into the Arkansas River Valley.

Land's End Cave is relatively small with the largest chamber rectangular in shape, approximately 30 m long, 20 m wide and 10-15 m high. Additional passages occur as narrow cracks and crevices that provide bat roosts nearly inaccessible to humans. There are no streams or permanent pools, but water does drip and seep along some walls, providing high humidity. The majority of the cave lies well below the entrance, creating a cold sink during winter months. Access to the interior of this cave is extremely difficult without the use of a rope, and this feature has probably allowed the bats to use more remote areas relatively undisturbed. However, the accumulation of trash at the base of the drop-off and knowledge of the cave's location among local residents suggests a significant level of disturbance at the cave entrance. The cave and associated sandstone bluff are on private property.

Three bats were removed from the cave wall for identification. Two specimens roosting solitarily were collected and identified as eastern pipistrelles *(Pipistrellus subflavus)*. The third specimen was removed from one of several clusters and identified as a male gray bat. Clusters were located on the face of an overhanging wall 2 to 4 m above the floor, and were estimated to contain 20 to 40 individuals each. The total number of bats present in clusters was estimated to be 150. All 3 bats examined were released. A single guano pile beneath a domed area of the ceiling indicated that gray bats or some other colonial species had utilized this cave during warmer periods of the year when bats were actively foraging. There was no evidence of guano accumulation beneath areas used by hibernating gray bats.

On 13 November 1990, the cave was visited again, and clusters of bats were observed at approximately the same locations on the cave wall. One bat was removed from a cluster and identified as a male gray bat. Several eastern pipistrelles were examined and released.

The cave was not visited between 13 November 1990 and 26 January 1991. On 27 January, we entered the cave and collected 3 eastern pipistrelles and a Rafinesque's big-eared bat *(Plecotus rafinesquii)*. These were released after identification, and no other species were seen.

On 15 February 1991, one of us (LEC) visited the cave entrance at dusk. Sounds emanating from the cave's interior suggested that large numbers of bats were present and active. Alight was shone into the cave and a large number of bats were observed flying about the chamber. Due to the cave's configuration, only a portion of the main room was visible. Clusters were not observed, nor was positive identification possible.

The cave was entered and searched again on 16 February 1991. Several eastern pipistrelles and 6 gray bats were observed. Five male and 1 female gray bats were in deep torpor. Two males roosted singly, 2 males roosted together, and a male and female roosted together. All individuals and pairs were spaced more than 1 m apart.

Two adult males with epididymides extended into their uropatagia weighed 10 g each and had left forearm (LFA) lengths of 43.6 and 43.9 mm. Three males did not exhibit epididymides in their uropatagia, and were presumed to be young-of-year. Young-of-year male gray bats undergo little or no spermatogenic activity and are infertile their first fall (Saugey, 1978). These bats weighed 8.75, 9.0, and 9.0 g and had LFA lengths of 42.1, 42.8, and 44.0 mm. The female weighed 9.5 g and had a LFA length of 43.5 mm.

The temperature and relative humidity recorded within 1 m of these bats was 7.5 C and 95%. Throughout their range, gray bats choose hibernation sites where temperatures average 6-11°C (Barbour and Davis, 1969). In northern Arkansas, Harvey *et al.* (1981) found ambient temperatures near hibernating clusters ranged from 10-12°C.

Temperatures recorded at the U.S. Army Corps of Engineers' weather station at the Dardanelle Lock and Dam were examined for the 14 day period prior to the influx of bats on 15 and 16 February. Daytime highs exceeded 15.5°C on 9 of these days, with a high of 21.1°C on 14 February (the day before the large number of bats was heard in the cave). Temperatures cooled to 11°C on 15 February, becoming dramatically colder with a high of 4.4°C on 16 February. We speculate that the high ambient temperatures on 14-15 February may have caused arousal of the bats, and that these bats returned to their preferred hibernation site (location currently unknown) when temperatures dropped on 16 February. Tuttle (1961) observed similar behavior by gray bats at a small cave in Tennessee.

Most gray bats migrate seasonally between hibernating and maternity caves. The distance travelled by individual colonies varies depending on geographic location (USFWS, 1982). Gray bats that hibernate in Arkansas are known to migrate to summer caves in Kansas, Missouri, and Oklahoma, and some gray

bats that hibernate in Missouri are known to summer in Arkansas caves (Harvey, 1989-90). Based on distances traveled between maternity sites and hibernacula in the Meramec River area of Missouri (LaVal and LaVal, 1980), distances from major maternity caves in northern Arkansas to this site are not excessive. Tuttle (1976) documented one-way migrations of gray bats between summer and winter sites of up to 525 km.

The occurrence of gray bats during the fall migratory period, and the accumulated pile of guano suggest this cave is used as a transitory or staging cave. However, the influx of gray bats in February, during the middle of the hibernating period indicates additional hibernacula likely exist in the area. It is highly unlikely that gray bats would move great distances in mid-winter due to the high energetic costs involved (Tuttle, 1976). Further, prior research has shown a strong site fidelity in gray bats to both winter and summer sites (Myers, 1964; Harvey, 1975; Tuttle, 1976; LaVal and LaVal, 1980). Tuttle's (1976) banding studies demonstrated that gray bats show lifetime fidelity to the hibernacula used during their first winter. This information, in conjunction with our discovery of gray bats at Land's End Cave, suggests that gray bats may have been wintering undetected in the Arkansas River Valley for some time.

This discovery constitutes a significant southward range extension for gray bats of at least 70 km from the other Arkansas caves known to house this species (Harvey *et al.*, 1981; *pers. comm.*, 1991). In addition, this report further emphasizes the need for additional field work in areas previously considered unlikely habitat, but which may contain pockets of suitable or marginal habitat (Gates *et al.*, 1984).

The gray bat may be more restricted to cave habitats than any other mammal in the United States (Hall and Wilson, 1966). Their requirements for roost sites and habitat are so specific, that fewer than 5% of available caves are suitable for occupation (Tuttle, 1979). Harvey (1989-90) estimated that gray bat populations in the cave region of northern Arkansas have declined as much as 61% in recent years. It seems especially timely then to re-evaluate the importance of fracture caves and mines, located in areas adjacent to known occupied habitat, in the natural history, distribution, and recovery of this endangered bat.

ACKNOWLEDGMENT

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AGGRESSIVE INTERACTIONS BETWEEN MALE COTTON MICE *(PEROMYSCUS GOSSYPINUS)* AND MALE TEXAS MICE *(P. ATTWATERI)*

Four species of *Peromyscus* (deer mouse, *P. maniculatus*; white-footed mouse, *P. leucopus;* cotton mouse, *P. gossypinus;* and Texas mouse, *P. attwateri*) are found sympatrically in the Ouachita Mountains and the southern Ozark Mountain region of Arkansas. Of these, *P. attwateri* is the most restricted in habitat, being found only in rock outcroppings of the Ouachitas and rock outcrops and cedar glades of the Ozarks (Sealander and Heidt, 1990). This restricted habitat has apparently resulted in some morphological and genetic differentiation, leading to lowered heterozygosity, between populations of *P. attwateri* (Kilpatrick, 1984; Sugg *et al.*, 1990). The reasons, however, for the observed habitat isolation of this species are not clear.

Brown (1964) demonstrated that male *P. leucopus* were highly dominant over male *P. attwateri*, and prolonged encounters often resulted in serious injury or death to the *P. attwateri*. Wolff (1985) has demonstrated that interspecific aggression between *P. leucopus* and *P. maniculatus* can influence home range size and location. Sugg *et al.* (1990) felt that interactions with congeners might also affect genetic variability in *P. attwateri* as has been suggested for other species of *Peromyscus* (Price and Kennedy, 1980). It may be that interspecific interactions between either *P. leucopus* or *P. gossypinus* and *P. attwateri* may contribute to the habitat restriction of the latter species.

The purpose of this study was to determine whether *P. gossypinus* or *P. attwateri* would be dominant in semi-forced encounters. As Brown (1964) primarily examined male-male interactions between *P. leucopus* and *P. attwateri* and male *Peromyscus* generally have larger home ranges and are more active (Madison, 1977; Metzgar, 1979; Myton, 1974; Taitt, 1981; Wolff, 1985), it was determined to only examine adult male mice in this study.

Mice used in this study (9 male *P. attwateri* and 7 *P. gossypinus*) were live trapped, using Sherman LFAGD traps baited with rolled oats and omaline, from their natural habitats in Hot Spring, Garland, and Montgomery counties, Arkansas. Animals were transported to the Basic Animal Services Unit at the University of Arkansas at Little Rock, housed individually in plastic cages (28.6 x 18.1 x 12.4 cm), maintained on a 12 hour light/dark cycle, and provided with water and Purina rat chow *ad libitum*. The animals were allowed to acclimate in the laboratory for a minimum of 30 days before they were tested.

Procedures for testing aggressive behavior primarily followed that of Ambrose and Meehan (1977). Testing was conducted in a plexiglass arena (54 x 69 x 44 cm) divided into two equal halves by a black, removable partition; the floor was covered by a 1 cm layer of ash wood chips. Encounters between experimental animals were done at night in a dark room illuminated by two 40 watt red lights.

Males of each species were randomly paired, placed on either side of the partition, and allowed to acclimate for 10-15 minutes. The partition was then removed and behavioral interactions were observed for 10-15 minutes. Numbers and times of conflict, postures (erect tail and ears, eye squinting, upright stance, pawing, rearing, and ducking), and overt movements (chase, lunge, and avoidance) were recorded. A confrontation occurred when there was overt interactions between the two individuals. Based on the criteria of Wolff *et al.* (1983), each confrontation was judged to be a win, draw, or loss.

A total of 39 trials was conducted which resulted in 192 confrontations. Of these, *P. gossypinus* were judged the winner of 115 (59.9%), *P. attwateri* 40 (20.8%), and 37 (19.3%) were considered draws. These data are highly significant (Chi Square, $P < 0.01$) and demonstrate the aggressive dominance of male *P. gossypinus* over male *P. attwateri* in this experimental paradigm.

Figures 1 and 2 illustrate individual results of each species. Only two *P. attwateri* were at all successful, accounting for 60% of this species' wins. On the other hand, the *P. gossypinus* wins were more evenly distributed, averaging 61% (ranging from 42 to 91%) of each individual's encounters.

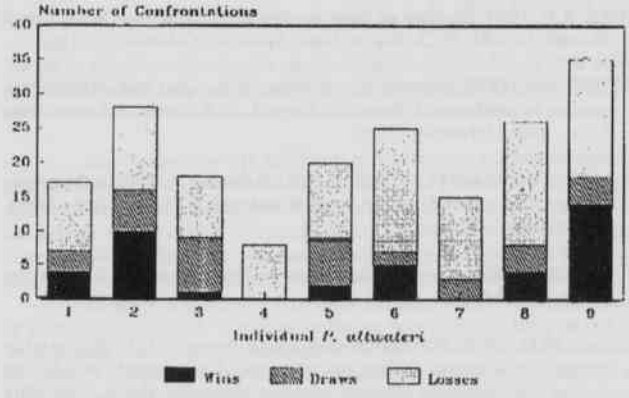

Figure 1. Percent of individual *P. attwateri* confrontational wins, draws, and losses.

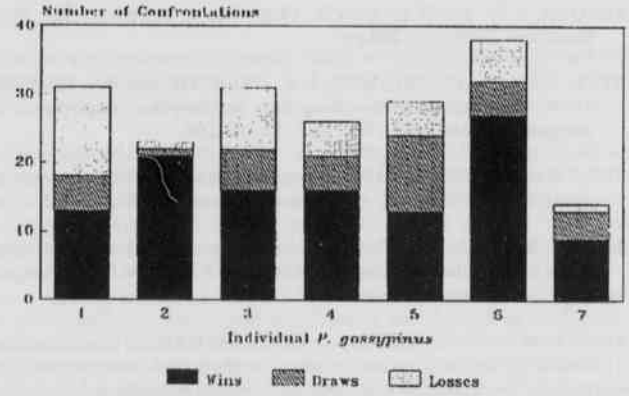

Figure 2. Percent of individual *P. gossypinus* confrontational wins, draws, and losses.

It may be argued that size may have contributed to the overall success of *P. gossypinus* as members of this species averaged 39.52 g, whereas *P. attwateri* averaged 24.52 g. To test this, a different experimental design would be necessary. However, Brown (1964) felt that the smaller *P. leucopus* was dominant over *P. attwateri* because of general temperament. Furthermore, Healey (1967) found no direct relationship within members of *P. maniculatus*.

In conclusion, while there are individual differences expressed between members of each species, this study demonstrated the dominance of adult male *P. gossypinus* over male *P. attwateri*. While nothing conclusive can be stated concerning the ecological isolation of *P. attwateri*, the results indicate that further research into aggressive behavioral interactions between these two species as well as *P. leucopus* is warranted.

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POSTERIOR MAXILLARY FANGS OF THE FLATHEAD SNAKE, *TANTILLA GRACILIS* (SERPENTES: COLUBRIDAE), USING SCANNING ELECTRON MICROSCOPY

Opisthoglyphous snakes constitute a group of more or less venomous, rear-fanged species within the family Colubridae (Smith, 1952; Fitch, 1970; Bellairs, 1970; Porter, 1972). The fangs reside on the posterior end of the maxillary bone and are larger, grooved, and often recurved compared to other maxillary teeth. Injection of venom into prey is accomplished by chewing the victims in the so-called "slash and swab" method (McDowell, 1986); the poison is released from the parotid gland (Duvernoy's gland) through a single duct which opens into a furrow along the lateral sides of the teeth.

The genus *Tantilla*, a New World group of small colubrid snakes comprising around 46 species, ranges throughout most of the southeastern and south-central United States (Telford, 1966) and is found in parts of the arid southwestern United States. The group is characterized by a combination of characters which includes the presence of posterior maxillary grooved teeth (Wilson, 1982). Hardy and Cole (1968) and Savitzky (1983) illustrated the maxillary bone of *Tantilla* and showed the grooved nature of the fangs; i.e., the grooves lie on the lateral face of the teeth. The present study examines the fangs and other maxillary teeth of the flathead snake, *Tantilla gracilis*, for the first time using scanning electron microscopy in order to reveal their surface morphology.

The left maxilla of 14 adult and juvenile specimens of *Tantilla gracilis* collected from the Interior Highlands of Arkansas were prepared for scanning electron microscopy (SEM). Each maxilla was removed using jewelers forceps and microscissors, stripped of muscle and connective tissue, and placed into vials of 70% ethanol. Routine laboratory techniques were employed to prepare teeth for SEM (Dawes, 1988). Maxillae were dehydrated in a graded series of ethanol and amyl acetate, dried with a Samdri critical point dryer, coated with gold/palladium in a Hummer IV sputter coater, and viewed with a JEOL100 CXII TEM-SCAN electron microscope at an accelerating voltage of 40 kV. All snakes and prepared tissues are deposited in the Arkansas State University Museum of Zoology.

All maxillary teeth of *Tantilla gracilis* showed varying degrees of structural modification (Figs. 1 and 2). The fangs are of two basic types: 1) curved and 2) linear. Also, the nature of the groove differed between these two types. Two fangs per maxilla is the general rule (excluding replacement fangs) in this species (Fig. 1B and E), although one specimen (Fig. 1D) exhibited three fangs. In most cases, fangs were separated from the anterior maxillary teeth by a space or diastema (Fig. 1G). The fangs of juveniles (Fig. 1A and B) are similar to those of adults (e.g., Fig. 1E) in that the fangs are curved, and the grooves project antero-laterally. However, the linear fang type is straighter, and grooves project laterally (Fig. 1C and D). The fang groove, a concavity running the entire labial surface of the fang, is situated between the mesial and distal surfaces; the groove is presumably formed by an expansion of dental ridges (Wright *et al.*, 1979; Vaeth *et al.*, 1985) that are characteristic of all maxillary teeth. The dental ridges are, however, more conspicuous in teeth near the fangs (Fig. 1F and G; Fig. 2D) compared to anterior teeth (Fig. 2C) and contribute to the semblance of grooves most noticeable on teeth near the fangs. Anterior maxillary teeth may also exhibit dental ridges that possess serrations (Fig. 2C), whereas, in other instances, these ridges appear smooth (Fig. 2D).

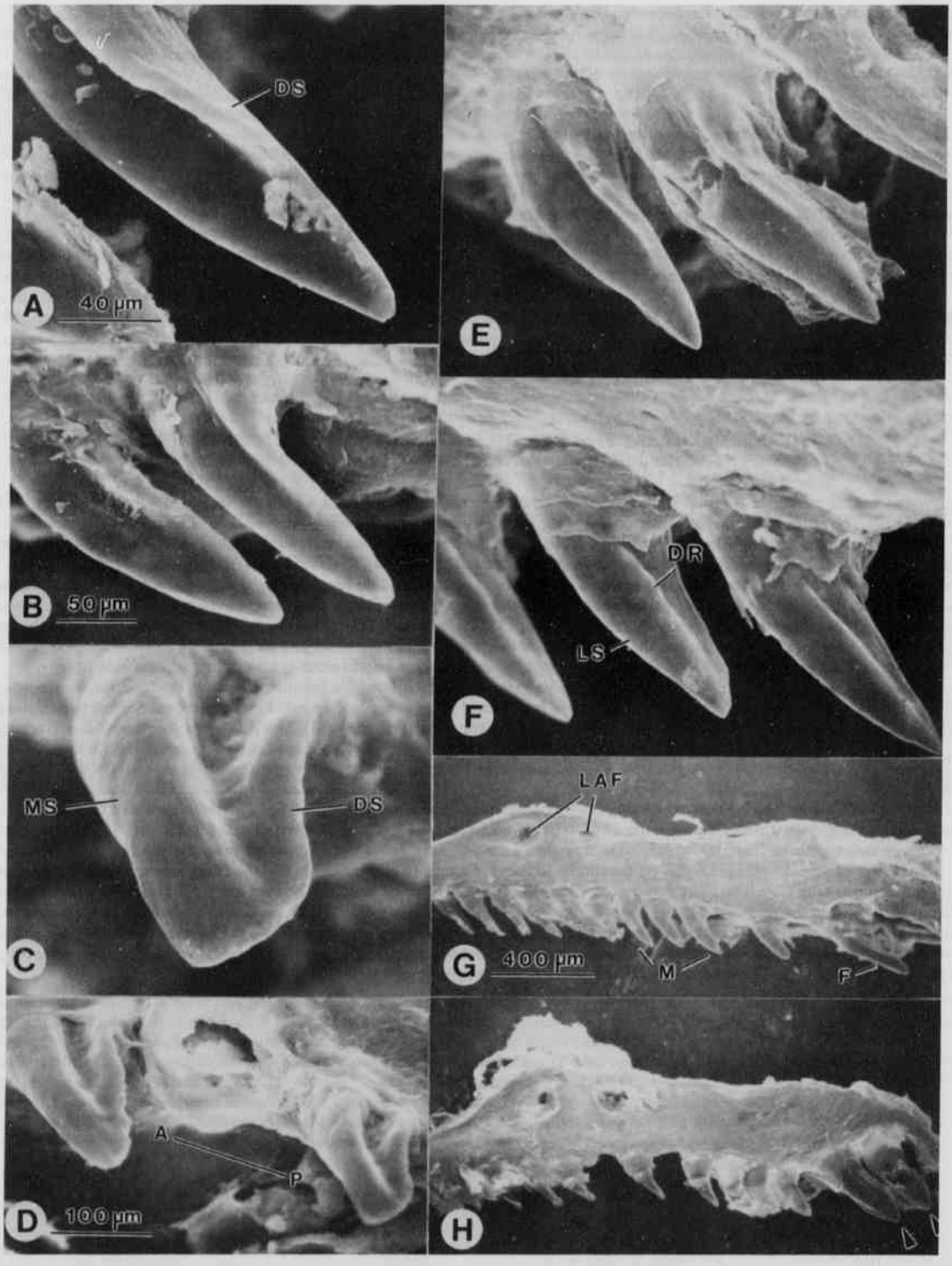

Figure 1. Scanning electron micrographs of maxillae and posterior maxillary fangs of *Tantilla gracilis*. Snout-vent length = SVL. A. Labial view of fang of a juvenile (87 mm SVL); DS= distal surface. B. Labial view of fangs of a juvenile (76 mm SVL). C. Ventral view of fang of adult male (147 mm SVL) illustrating the mesial (MS) and distal surfaces (magnification the same as A). D. Adult male (in C) exhibiting three fangs (middle one broken off). The anteroposterior axis of the maxilla (A-P) showing grooves of fangs facing outward. E. Fangs of an adult male (152 mm SVL); magnification the same as in D. F. Maxillary teeth craniad to fangs showing apparent grooves; LS = labial surface; DR= dental ridge. Magnification the same as in B. G. Maxilla of an adult female (137 mm SVL); LAF= lateral anterior foramina; M = maxillary teeth (same as in F); F = fang. H. Maxilla of an adult male (in E). Arrows point to fangs (magnification as in G).

General Notes

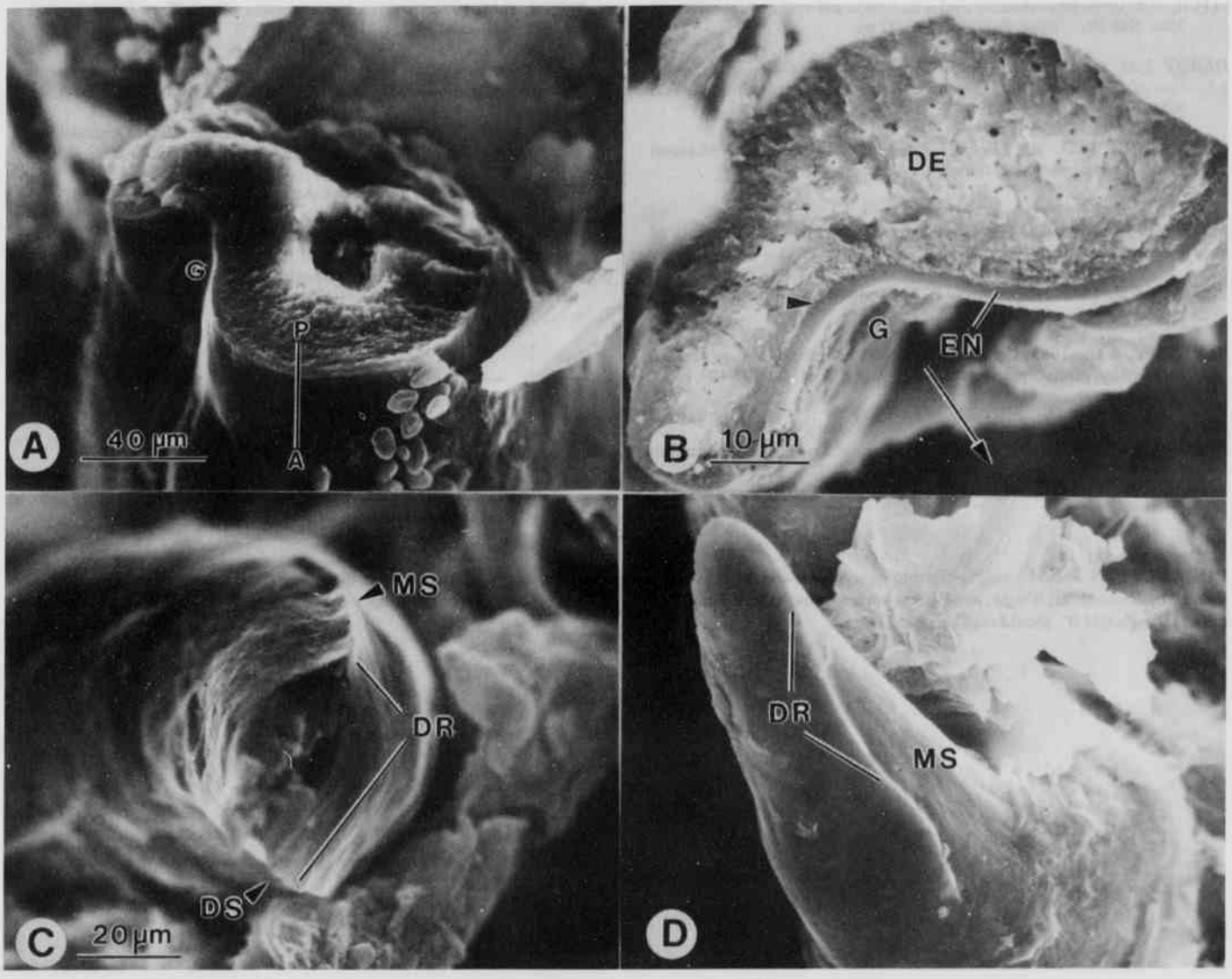

Figure 2. Scanning electron micrographs of maxillary fangs and anterior maxillary teeth of *Tantilla gracilis*. A. Cross section of a fang broken near its base. The anteroposterior axis (A-P) of the maxilla reveals groove (G) facing slightly craniad and shows the mesial portion of tooth which is larger than the distal portion. B. Magnification of A. Pointer separates the outer enamel layer (EN) from the inner dentine (DE). Notice the dentine is quite porous. Arrow points laterally. C. End-on view of an anterior maxillary tooth (tip broken off) showing serrated dental ridges (DR) on both the mesial and distal surfaces. D. Anterior maxillary tooth showing dental ridge on mesial surface. Magnification as in A.

Tantilla gracilis feeds primarily on arthropods (Carpenter, 1958; Collins, 1982; Johnson, 1987) and, especially, their soft-bodied larvae. As with other insectivorous, opisthoglyphous snakes (Savitsky, 1983; Vaeth *et al.*, 1985), the anterior maxillary teeth of *T. gracilis* primarily serve to engage and penetrate prey. Then, immobilization of prey is accomplished by venom injection using the posterior maxillary fangs.

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CORRECTION – In the article "Sexual dimorphism and intersexual differences in resource allocations of a dioecious shrub, *Lindera melissifolia* (Walt.) Blume" by Richardson, Wright, and Walker which appeared in Volume 44 (1990) of the Proceedings of the Arkansas Academy of Science, Page 101, Column 2, Line 11, "male 623.0" should read "male 62.0".