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Academy Editors

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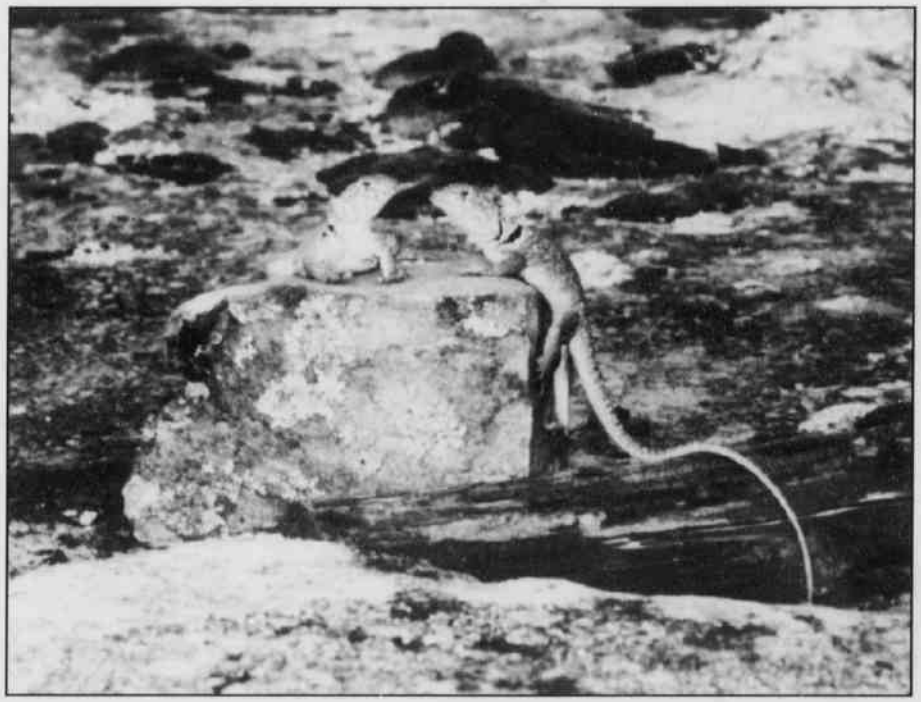
VOLUME 52
1998



ARKANSAS ACADEMY OF SCIENCE
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E. Leon Richards, 1980
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David Chittenden, 1989
Richard K. Speairs, Jr. 1990
Robert Watson, 1991
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George Harp, 1994
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James Daly, 1998

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UNIVERSITY OF THE OZARKS, Clarksville
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EDITORIAL STAFF

EDITOR: STAN TRAUTH, Dept. of Biological Sciences, Arkansas State University, State University, AR 72467-0599.

NEWSLETTER EDITOR: DAVID A. SAUGEY, U. S. Forest Service, Ouachita National Forest, Jessieville, AR 71949.

BIOTA EDITOR: DOUGLAS A. JAMES, Dept. of Biological Sciences, University of Arkansas at Fayetteville, Fayetteville, AR 72701.

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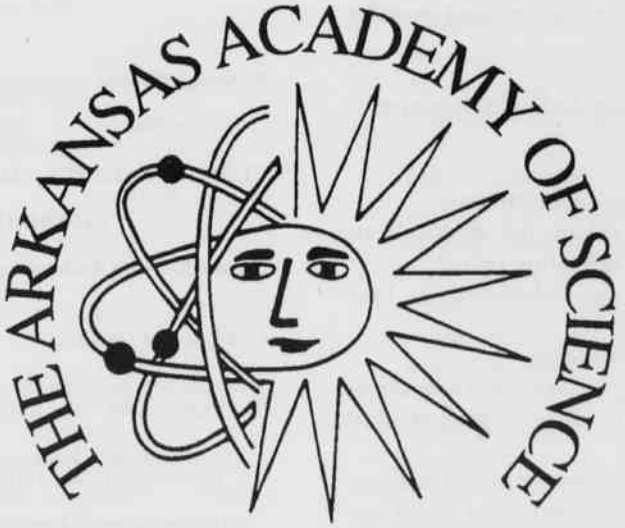
COVER: Adult male and female collared lizards (*Crotaphytus collaris*) from a cedar glade near Calico Rock, Arkansas. Photo by Stan Trauth.

Arkansas Academy of Science 1998



April 3-4, 1998
82nd Annual Meeting

University of Arkansas for Medical Sciences

JOURNAL
ARKANSAS ACADEMY OF SCIENCE

ANNUAL MEETING 3-4 APRIL 1998
UNIVERSITY OF ARKANSAS FOR MEDICAL SCIENCES

James Daly
President

Rose McConnell
President-Elect

John D. Rickett
Secretary

Joyce Hardin
Treasurer

NAAS Delegate

Henry Robison
Historian

Secretary's Report

MINUTES OF THE 82ND MEETING

FIRST BUSINESS MEETING
3 APRIL 1998

Number present: 19

President-Elect Rose McConnell called the meeting to order at 1108 and welcomed all attendees.

McConnell recognized the following individuals/committees for reports

1. Wayne Gray, Local Arrangements Committee:
   (a) Gray asked if anyone had ridden the shuttle from the Hilton to be sure it was operating (at is);
   (b) eighty-seven presentations are scheduled in four concurrent session each day;
   (c) received about 100 pre-registrations;
   (d) keynote speaker is Dr. Gregory Wilson, Director of NASA Lab in Huntsville, AL. He will speak at 1630 hrs.;
   (e) evening events will be a reception at the Discovery Museum and meal catered by Corky's at the River Market with musical entertainment by Lark of the Morning.

2. John Rickett, Secretary:
   (a) asked members to read and look for errors in minutes of the 1997 Business Meetings, and motion for approval, pending changes, will be made at the second business meeting;
   (b) membership report: 186 regulars; 47 lifers; 48 students; 17 sustaining; 1 sponsoring; and 2 sponsoring/conditionl life members (total: 301). The recent trend has been downward, and should we be concerned? Submit any ideas for recruitment to J. Daly (when his health improves). Joe Guenter asked if the decline has been caused by lack of interest or forgetfulness. Rickett opined that its probably mostly lack of interest and mentioned specifically young faculty in the state who aren't getting involved.

3. Joyce Hardin, Treasurer: reviewed the financial statement briefly, emphasizing major sources of income, investments and expenses, and asked for questions–none came.

FUNDS

Beginning Balance - 1 January 1997	**$20,512.95**
Net Gain 1997	2.227.96
CLOSING BALANCE - 31 DECEMBER 1997	**$22.740.91**

DISTRIBUTION OF ACCOUNTS

Interest Bearing Checking Account (Mercantile Bank, Conway, AR)	2.949.86
Certificates of Deposit	
Dwight Moore Endowment (Mercantile Bank, Conway, AR - No. 175192 - 5.2% Int.)	3,646.15
Life Membership Endowment (Mercantile Bank, Conway, AR - No. 175193 - 5.2% Int.)	12,144.90
CD Unrestricted (Mercantile Bank, Conway, AR - No. 175443 - 5.2% Int.)	4,000.00
TOTAL	**$22,740.91**

Respectfully Submitted,

Dr. Joyce M. Hardin, AAS Treasurer

Financial Statement, Arkansas Academy of Science

INCOME: 1 January 1997 to 31 December 1997

1. INDIVIDUAL MEMBERSHIPS		
a. Regular	2,405.00	
b. Sustaining	175.00	
c. Life	375.00	
d. Associate	360.00	
	3,615.00	3,615.00
2. INSTITUTIONAL MEMBERSHIPS		1,500.00

3. PROCEEDINGS, SUBSCRIPTIONS		5,161.30
4. PROCEEDINGS, MISC. SALES		200.00
5. PROCEEDINGS, PAGE CHARGES		4,960.00
6. INTEREST		
a. Interest Bearing Checking Account (1/97 - 7/97)	99.14	99.14
7. ANNUAL MEETING		2,711.15
8. ENDOWMENT DONATIONS		
a. Dwight Moore Endowment	30.00	
b. AAS Endowment	4,940.29	
c. AAS Graduate Research	125.00	
d. AAS Undergraduate Research	125.00	
e. AAS Publication	25.00	
	5,245.29	5,245.29
TOTAL INCOME		**$23,491.88**

Financial Statement, Arkansas Academy of Science

EXPENSES: 1 January 1997 to 31 December 1997

1. AWARDS		
a. Conway Trophy & Awards, Plaques - Arkansas Science Talent Search (#695, #001)	318.00	
b. Arkansas Science Fair Association (#687)	450.00	
c. Arkansas Junior Academy of Science (#688)	250.00	
	1,018.00	1,018.00
2. PROCEEDINGS		
a. Stan Trauth -Editorial Consultation and Travel Vol. 50 (#679)	200.00	
b. Creative Multigraphics Vol. 50 (#684)	11,940.75	
c. Joy Trauth -Editorial Consultant Vol. 51 (#673)	500.00	
	12,640.75	12,640.75
3. OFFICE EXPENSES		
a. Secretaries Office - John Rickett (#693)	520.83	
b. Treasurer's Office - Joyce Hardin (#603)	10.60	
	531.42	531.43
4. ANNUAL MEETING		1,795.25
5. NEWSLETTERS		
a. UALR - Postage Fall 1996 Newsletter (#678)	58.69	
b. Kwik Print - Spring 1997 Newsletter (#680)	287.55	
c. UALR - Postage Spring 1997 Newsletter (#681)		57.30
	403.54	403.54
6. DUES		
National Association of Academies of Science (#602)		62.50
7. BANK CHARGES		
Mercantile Bank - New checks and deposit slips		70.65
8. SERVICE CHARGES		
Union Bank - Monticello		19.90
9. TRANSFER TO CD (Unrestricted)		4,000.00
TOTAL EXPENSES		**$20.542.02**

4. Stan Trauth, *Journal* Editor: Stan presented a copy of Volume 51; it is larger and less expensive than Volume 50 and explained that he had worked with a different printer. Stan also presented his plan for restructuring the Editor's office; he proposes an Editor-in-Chief, a Managing Editor and a better organized group of Associate Editors; and asked for discussion. No discussion came. Bill Shepherd moved (2nd: Hemmati) the plan be accepted. Daly suggested that Stan move up to Editor-In-Chief and occupy that office for two years during the transition. Bill Shepherd suggested that both Editors should be on same campus for ease of working together. Stan agreed to discuss it.

5. David Saugey, *Newsletter* Editor: Saugey asked for specific news items and for individuals to serve as campus representatives or spokespersons to gather information and send it to him. He also explained that time sequencing in getting meeting information may cause the *Newsletter* to be a little late sometimes–just be patient or call him. Saugey moved (2nd: Hemmati) that the Academy set aside $500 to support the preparation and mailing of the Newsletter over the coming year.

6. Mike Matthews, Nominations Committee (Mike Rapp and Art Johnson, members): Matthews distributed a list of two nominees, William Willingham (Chemistry, UAPB) and Mark Draganjac (Chemistry, ASU). Daly moved (2nd: Hemmati) to accept the committee's report. MeConnell asked for nominations from the floor but none came.

7. Doug James, Biota Committee: James not present; no report.

8. Jim Daly, Development Committee: Daly plans to sends out recruitment letters to campus administrators with information regarding the Academy and encourage them to encourage their people to become involved with the Academy. Matthews moved (2nd: Hernmati) to accept Daly's report.

9. Steve Runge, Westinghouse/Arkansas Science Talent Search: Runge not present; no report.

10. Tom Palko, Junior science & Humanities Symposium: Palko not present; McConnell read a report (Appendix A).

11. Bob Skinner, Junior Academy of Science: Skinner not present; McConnell read a report (Appendix C).

12. Mike Rapp, State Science Fair Assn: Rapp not present;

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McConnell read a report in which Rapp requested $450 and $250 for the State Science Fair Assn. and Junior Academy of Science, respectively, for the coming year's activities. Hemmati moved (2nd: Joe Guenter) moved to accept the read reports and the funding requests (Appendix B).

13. McConnell appointed Bob Wiley and Dick Kluender as the Auditing Committee.

14. McConnell appointed Mostafa Hemmati, Chair, Wayne Gray and Rudy Eichenberger as the Resolutions Committee.

15. McConnell appointed an *ad hoc* Constitution Committee (John Rickett, Chair, and _____) to work on changes pertaining to the journal title and the editorial office.

16. Henry Robison, Historian: Robison not present; McConnell read a report.

17. McConnell asked for additional old business; none came.

18. McConnell asked for new business:
Daly suggested the Academy draft a letter to President Sugg to support the continuance of operation of the University of Arkansas Press. Daly moved (2nd: Hardin).

19. McConnell made the following announcements:
    a. There will he no Sigma Xi breakfast;
    b. Authors planning to publish must turn in manuscripts to section chairs or Stan Trauth;
    c. Section chairs need to keep their sessions on schedule;
    d. The Arkansas Avian Viability Assessement Committee will meet tomorrow immediately following the 2nd business meeting.

20. McConnell adjourned the meeting at 1155.

SECOND BUSINESS MEETING
4 APRIL 1998

Number present: 58

President-Elect Rose McConnell called the meeting to order at 1113 hrs. and recognized the following persons for reports/business items:

1. Secretary: J. Rickett noted that copies of minutes of last year's business meetings were available at the door and reminded attendees of yesterday's presentation of the minutes and moved their approval. No corrections were received and minutes were approved by voice vote.

2. Nominations Committee: (M. Mathews, M. Rapp and A. Johnson) Mark Draganjac and William Willingham have been nominated for the Vice President's election. McConnell asked for nominations from the floor, none came, and Doug James moved (2nd: Walt Godwin) that nominations ceased. Motion passerd, and ballots were distributed.

3. Treasurer: J. Hardin noted that copies of the financial report were available at the door, then reviewed the Academy's income, investments and expenses. She observed that the pre-payment of page charges has given us more breathing room in that we can now pay for the *Journal* without cashing in CDs. She also pointed out that David Saugey has been instrumental in setting up a way to contribute leftover monies from another meeting to the Academy. McConnell then recognized the Auditing Committee which reported that the books were in order. The Treasurer's financial statement was approved.

4. Biota Committee: D. James reported that no new lists have been received, so they are beginning the process of reviewing the old lists to update and prepare them for "commercial" publication. Trauth moved (2nd: Mathews) to accept his report. Passed.

5. Avian Viability Assessment Committee: Tom Foti described the function of the committee as providing the Natural Heritage Commission and Arkansas Game & Fish Commission with information to rank and prioritize management/restoration projects because of limited funds. The thrust will move later to other faunal groups.

6. Historian: H. Robison reported this is the eighth time for the Academy to meet on the UAMS campus. Other years were 1943, 1944, 1945, 1947, 1949, 1958 and 1989.

7. *Journal* Editor: Stan Trauth described his proposed reorganization of the journal preparation process. He proposed that a new position, Editor-in-Chief, be erected, that the current Editor's position be renamed "Managing Editor" and be elected. After serving as Managing Editor, the individual would move up to Editor-in-Chief. Considerable discussion followed regarding status in the Executive Committee, justification, length of terms, and other details. Trauth moved (2nd: Daly) for adoption and motion passed by voice

vote. McConnell charged the *ad hoc* Constitution Committee to affect the proper alterations then appointed another *ad hoc* committee (Stan T., D. Kluender and _____) to find a new editor. (Secretary's Note: normally the details of such a change in officer structure are hammered out by an *ad hoc* committee first [not by a constitution revision committee], then brought to the membership for final discussion and approval (or denial). I think our Constitution would still adjure us to follow this more prudent procedure; if not, the membership may rescind this vote at next year's meeting.

8. McConnell called for volunteers to assist Rickett on the *ad hoc* Constitution Committee; no volunteers appeared.

9. *Newsletter* Editor: Saugey said he will be contacting institutions and individuals for information for the *Newsletter.* He also reminded Academy members to understand that he must receive information regarding the next meeting before he can prepare the *Newsletter,* consequently it may be a little later than first anticipated.

10. Ancillary organizations:
    a. Westinghouse/Arkansas Science Talent Search: no representative was present to report; we assumed they need $200 of continued funding for the coming year.
    b. Junior Science & Hujmanities Symposium: (see Appendix A for report)
    c. State Science Fair Association: (see Appendix B for report); continued funding request of $450.
    d. Junior Academy of Science: (see Appendix C for report); continued funding request of $250.
    e. Robison moved (2nd: W. Godwin) that we continue these levels of support. Motion passed.

11. McConnel recognized Jim Daly to restate his motion that the Academy to draft a letter of support for the continuance of operation of the University of Arkansas Press. Passed.

12. Resolutions Committee (Mostafa Hemmati, Wayne Gray and Rudy Eichengerger): (see Appendix D for resolutions). Kluender moved (wnd: Godwin) that the resolutions be accepted. Passed.

13. Awards Committee: W. Gray (for Mike Soulsby) and Amy Wilson, representing the Arkansas Environmental Federation: (see Appendix E for list of awardees).

14. Meeting results and data (W. Gray): 230 registrations (about 100 pre-registered); 125 attended the banquet; 87 presentations, 45 of which were student papers.

15. McConnell called for any other old business; none came.

16. McConnell then announced the new Vice-President is Mark Draganjac.

17. McConnell asked for new business:
    a. Calvin Cotton suggested we need a permanent website. McConnell asked for a motion to set up a committee. Cindy Kane so moved (2nd: Matthews); approved, and McConnell named Mark Draganjac, Calvin Cotton and Walt Godwin to an *ad hoc* committee. Cotton also volunteered to work on a new logo for the Academy and moved (2nd: Robison) that we commission him to do so. Motion passed. Cotton would welcome input.
    b. No other new business came forth.

18. McConnell made the following announcements:
    a. Pick up and deliver unclaimed journals back to your respective campuses;
    b. Give manuscripts to Stan Trauth;
    c. The Avian Viability Committee will meet immediately following this one;
    d. Thanks to Wayne Gray for chairing the Local Arrangements Committee.

19. MConnell recognized Dick Kluender who presented Bob Wiley with a plaque of appreciation for his 10-year (two terms) service as Treasurer.

20. McConnell then recognized out-going President Jim Daly with a plaque of appreciation. Daly then officially recognized Rose McConnell as the incoming President and adjourned the meeting at 1337 hrs.

Respectfully submitted,

John Rickett, Secretary
20 April 1998

APPENDIX A

JUNIOR SCIENCE AND HUMANTIIES SYMPOSIUM

The 32nd Arkansas JSHS was held on Arkansas Tech University campus March 27–29, 1998. Science students and teacher delegates from across the state attended the program. Featured were the oral presentations of the 16 student finalists in the paper competition, lectures by scientific

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researchers, tours of the science and engineering departments at ATU and a poster contest to display individual student research.

Geoffrey Schmidt from Little Rock Central High School was awarded first place in the oral research paper presentation and received a $4,000 scholarship from the National JSHS. He and five other students were selected to attend the National JSHS in Albuquerque, NM later this month. Geoff will present his paper on computer programming, "Two new tools for visible surface determination", and will compete in the national student research paper competition. Tom Palko, Director, will accompany the students to the national symposium. Four other studens received scholarships to Arkansas Tech University. Cash prizes were awarded to the winners in the two divisions of the poster contest, the small schools and the large or magnet schools.

Delegates enjoyed musical productions, which included operetta selections and a program of harpsichord, piano and organ music by faculty and students of ATU. The delegates also participated in social mixers which enabled them to become better acquainted.

The 33rd Arkansas JSHS will be held at Arkansas Tech University on March 26-28, 1999.

Tom Palko, Director
3 April 1998

APPENDIX B

STATE SCIENCE FAIR ASSOCIATION

Thank you for the support the Academy has provided for the past 15 years, both in terms of members of the AAS serving as judges and in terms of financial support. This memo serves as a report of the Science Fairs held in Arkansas during 1998:

Central (held at UAMS, Mar 14): Margie Snider, fair director, and Marian Douglas, Jr. Acad. director. 340 students participated.

Northcentral (Lyon College, Batesville. Mar 13): Beverly Meinzer, fair director, and Kathy Campbell, Jr. Acad. director. 266 students participated.

Northeast (Ark. State Univ., Jonesboro, Feb 27, 28): Larry Mink, fair director, and Ron Johnson, Jr. Acad. director. 136 students participated.

Northwest (Univ. of Ark. at Fayetteville, Mar. 13): Lynne Hehr, fair and Jr. Acad. director. 341 students participated.

Southcentral (Henderson State Univ., Arkadelphia, Mar 6). Joe Bradshaw, fair director, and Lisa Cobb, Jr. Acad. director, 153 students participated.

Southeast (Univ. of Ark. at Monticello, Mar 13): Jim Leslie, fair director. 235 students participated.

Southwest (Southern Ark. Univ., Magnolia, Mar 13): Daniels, fair director. 213 students participated.

Westcentral (ASMS, Hot Springs, Mar 2-6): Alecia Castleberry, fair director, and Shane Wilbanks, Jr. director. 225 students participated.

Approximately 260 students are expected to register for the state science fair, to be held April 3, 4 at the Univ. of Central Arkansas in Conway.

A request for funding for the Arkansas Science Fair Association follows:

"The Arkansas Science Fair Association requests the Arkansas Academy of Science to continue its support for the past 12 years of $50 to each of the nine science fairs in Arkansas that will send students and teachers to the International Science and Engineering Fair, to be held in May, 1998 in Fort Worth, Texas. The total contribution being sought is $450."

Should the membership approve this request, please make the check payable to "Arkansas Science Fair Association" and mail it to Dr. Mike Rapp, Department of Chemistry, Univ. of Central Arkansas; Conway, AR 72035.

Mike Rapp, Director

APPENDIX C

ARKANSAS JUNIOR ACADEMY OF SCIENCE

Seventy-four students from six of the eight regions and representing 12 high schools participated in the AJAS state contest held at the Univ. of Central Arkansas on April 12, 1998 follow:

students: 74 (+9) entries: 70 (+7)
9th grade: 4 (+3)
10th grade: 14 (-4)
11th grade: 32 (+8)
12th grade: 20 (+2)
(four did not list grade)

Nine school had students who won awards:

ASMS: 23 category awards; two overall
Central: 13 category awards; four overall, top student
Mills: five category awards; one overall
Harmony Grove: four category awards

Three students, who won the Junior/Sophomore Division in 1997, and two teacher-sponsors attended the American Junior Academy of Science . The students were

Geoffry Schmidt, Freddy Nguyen and Sapan Shah, and the teachers were Gary Hufford and Gary Earleywine. The Arkansas Junior Academy paid half of the travel and registration fees for one student and one teacher, a total of $820. This meeting was held in conjunction with the meeting of the American Association for the Advancement of Science.

The Arkansas Junior Academy thanks the Academy of Science for its continued encouragement and monetary support and requests continued support of $250 for the coming year's activities.

Robert D. Skinner, Director
3 April 1998

(Secretary's Note: an inconsistency between this report and Rapp's report occurs regarding the date of meeting (April 12 vs. April 13). Rapp's report states the two organizations met together.
George Harp

APPENDIX D

RESOLUTIONS

BE IT RESOLVED that we, the membership of the Arkansas Academy of Science, offer our sincere thanks to the University of Arkansas for Medical Sciences for hosting the 1998 meeting of the Arkansas Academy of Science. In particular, we thank the Local Arrangements committee, Wayne Gray, Chair, George Blevins, Parimal Chowdhury, Jim Daly, Kim Fifer, Cindy Kane, Lisa Maddox, Mark McCammon, Dorothy Miles and Michael Soulsby, and all the student workers and staff who collectively contributed to a very successful meeting. Appreciation is expressed for the use of the excellent facilities and the hospitality shown to us by all University of Arkansas for Medical Sciences personnel. We truly appreciate Dr. Gregory Wilson and his graphic presentation of "Space Science: NASA's Investment in America's Future."

"The Academy recognizes the important role played by the various section chairpersons and expresses sincere appreciation to John Bush and Joyce Hardin (Aquatic and Environmental Sciences/Invertebrate Zoology); Tom Kelly and Dennis Baeyens (Biomedical Sciences), Cesar Compadre, John Sorenson and Ali Shaikh (Chemistry); Robert Engleken, W. J. Braithwaite, Roger Hawk and Edwin Braithwaite (Physics/Physical Science); Marie Chow and Scott Kirkconnell (Microbiology); Stan Trauth and Gary Heidt (Vertebrate Zoology).

A special thanks is owed to individuals devoting considerable time and energy to judging student papers: Mostafa Hemmati, Richard Komoroski, Rudy Eichenberger, Jeff Robertson, Jerry Webb, Victor Samokyszyn, Chidambaram Bhuvaneswren, Lamar Setliff, Jay Gandy, Richard Kluender, Hershel Conway, David Wennerstrom, David Davies, Midhael Matthews, Robert Wiley and Clifton Orr.

The Academy appreciates UAMS for sponsoring the Friday evening social, the Arkansas Environmental Federation for funding the undergraduate presentation awards and Sigma Xi for funding the graduate presentation awards.

We express gratitude to the various directors of the science and youth activities which are supported and/or supervised bv the Academy: Jim Edson (Chair of the Science Education Committee), Mike Rapp (Director of the Arkansas State Science Fair Association, Tom Palko, (Director of the Junior Science & Humanities Symposium, Steve Runge (Director of the Westinghouse/Arkansas Science Talent Search and Robert and Raynell Skinner (Co-directors of the Junior Academy of Science).

We wish to thank all those who served as directors at the regional science fairs and Junior Academy meetings: (see Appendix B).

The continued success of the Academy is due to leadership. We offer sincere thanks to our officers for another excellent year: James Daly (President), Rose McConnell (President-Elect), Mostafa Hemmati (Vice President), John Rickett (Secretary), Joyce Hardin (Treasurer), Richard Kluender (Past President), Stan Trauth (*Journal* Editor), David Saugey (*Newsletter* Editor) and Henry Robison (Historian). In addition, the Academy expresses appreciation to all who contributed time and effort on various committees of the Academy.

Finally, we congratulate all who presented papers and posters at this meeting. Student participants are especially recognized since their continued efforts and contributions will be directly responsible for the future success of the Academy and its programs for the continuing improvement and advancement of science education and research in Arkansas.

Respectfully submitted,
Mostafa Hemmati, Chair
Wayne Gray
Rudy Eichenberger

APPENDIX E

STUDENT AWARDS

Physics undergraduate:

Clayton Workman (ASU), "Improvement in the electroplating of $CuInS_2$"

Anthony Bednar (ASU, "Infrared laser spectroscopy of jet cooled molecules"
Candance Lindsey (ASU), "Infrar-ed laser spectroscopy of jet cooled manganese pentacarbonyl halides"

Physics graduate:

Timothy Wofford (UALR), "A study of ruthenium oxide coating for use in thin film capacitors"
Richard Homard (UALF), "Low power diode lasers for raman spectroscopy"

Chemistry undergraduate:

James Sheet.s (UALR), "4-Nitrobiphenyls: synthesis and mutagenecities"
Kathy Herrin (Harding), "Tropospheric lifetime of hydroflurocarbons"
Justin Scarbrough (ASU), "Stereoselective synthesis of beta-deuterated, leucine from, asymmetric reduction of isobutyr (aldehyde-d) for use in solution-phase protein structure determination"

Life Sciences undergraduate:

Ruussel Robertson (Hendrix), "G proteins and calcium channels affect halothane sensitivity in *Caenorhabits elegans*"
Brad Clark (UCA), "Differential gene expression in C3H-1OT1/2 cells undergoing apoptosis due to intracellulr acidification"
Kristy Jones (John Brown U.), "*In vitro* growth characterisitics of two *Cryptococcus neoformans* isolates"

Life Science graduate:

Lisa Maddox (UAMS), "The role of inducible nitric oxide synthase during renal ischemia-reperfusion injury"
Allen Dye (UAMS), "Giardiasis in Arkansas: Age distribution and the *Giardia* season"
Chaojie Zhang (UAMS), "Angiotensin II signal activates the NO-cGMP pathway in rat proximal tubules"

Environmental Sciences undergraduate:

Lori Sale (ATU), "Coliform evaluation and source determination for the river valley waterways"
Chad Hargrave (UAF), "Current status of Arkanss darter *(Etheostoma cragini)* and least darter *(E. microperca)* in Arkansas"
Amy Hardwick (UAF), "The *Amoeba* biota of Piney Ditch Swamp, Monroe County, Arkansas"

Environmental Sciences graduate:

Robin Roggio (UAF), "Effects of agricultural practices on water quality and nutrient transport in two small watersheds, northwestern Arkansas"

MEMBERS 1997

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PROGRAM

Arkansas Academy of Science

82nd Annual Meeting

April 3-4, 1998

University of Arkansas for Medical Sciences

SCHEDULE OF EVENTS

Friday, April 3, 1998

11:00 am. - 4:00 p.m.	Registration	EDII Bldg. G level
10:45 a.m. - 2:30 p.m.	Shuttle transport from Hilton Hotel to meeting	
8:30 am. - 10:30 a.m.	Executive Committee Meeting	EDIII Bldg., Room G222
11:00 a.m. - 12:00 p.m.	First Business Meeting	EDIII Bldg., Room G230
1:00 p.m. - 4:00 p.m.	Paper Sessions	EDII Bldg., G and B level 5
	Physics/Physical Science I	EDII Bldg., Room G137
	Aquatic/Environmental Science Invertebrate Zoology	EDII Bldg., Room G106
	Biomedical Science	EDII Bldg., Room G110
	Chemistry I	EDII Bldg., Room B107
	Poster Session	EDII Concourse
2:15 p.m. - 3:45 p.m.	Refreshments	EDII Concourse
4:15 p.m. - 4:30 p.m.	Welcome & Announcements	EDII Bldg., Room G141
4:30p.m. - 5:30p.m.	Keynote Speech Dr. Gregory Wilson, NASA *"Space Science: NASA's Investment for America's Future"*	EDII Bldg., Room G141
5:00 p.m. - 6:00 p.m.	Shuttle from UAMS to Hilton Hotel	
1:00 p.m. - 4:00 p.m.	Poster Session	EDII Concourse
6:00 p.m. - 7:30 p.m.	Social Mixer	Museum of Discovery
7:15 p.m. - 8:30 p.m.	Buffet Dinner	River Market W. Pavilion
6:00 p.m. - 9:00 p.m.	Admission to Museum of Discovery Shuttle from Hilton to River Market and back	

Saturday, 4 April 1998

8:00 a.m. - 10:00 am.	Registration	EDIII Bldg. Lobby
8:00 a.m. - 11:45 am.	Paper Sessions	EDII Bldg., G and B level
	Physics/Physical Science II	EDII Bldg., Room B107
	Zoology	EDII Bldg., Room G137
	Chemistry II	EDII Bldg., Room G106
	Microbiology	EDII Bldg., Room G110
	Poster Session	EDII Concourse
9:30 a.m. - 10:30 p.m.	Refreshments	EDII Concourse
9:30 a.m. - 10:15 am.	UAMS campus tours	Start EDII, Room G112
12:00 p.m. - 1:00 p.m.	Second Business Meeting Award Presentations	EDII Bldg., Room G137

SECTION PROGRAMS

* Undergraduate **Graduate

PAPER SESSIONS

Aquatic and Environmental Science/Invertebrate Zoology
Location: EDII Bldg., Room G106

Chairpersons: Dr. John Bush, University of Arkansas at Little Rock
Dr. Joyce Hardin, Hendrix College

Time — Topic

1:00 — Michael E. Cartwright, Stanely E. Trauth and J. D. Wilhide. Arkansas Game and Fish Commission, Calico Rock, AR 72519, and Department of Biological Sciences, Arkansas State University, State Univ., AR 72467. **WOOD FROG (*RANA SYLVATICA*) USE OF WILDLIFE PONDS IN NORTH-CENTRAL ARKANSAS.**

1:15 — Staria S. Vanderpool and E. Leon Richards, Department of Biological Sciences, Arkansas State University, State University, AR 72467. **A FLORISTIC INVENTORY OF THREE BOGS ON CROWLEY'S RIDGE IN NORTH-EAST ARKANSAS.**

1:30 — Chris L. Davidson[1], John L. Harris[2], and George L. Harp[2], [1]University of Arkansas at Pine Bluff, Agriculture/Fisheries Center, 1200 N. University, Box 4912, Pine Bluff, AR 72611, [2]Arkansas State University, Department of Biological Sciences, State University, AR 72467. **DISTRIBUTION AND COMMUNITY STRUCTURE OF MUSSELS**

(SUBORDER: UNIONACEA) INHABITATING OZARK AND DARDANELLE LAKES, ARKANSAS.

1:45 *Theo Witsell and William Shepherd, Arkansas Natural Heritage Commission, Little Rock, AR 72201. **REDISCOVERY AFTER 162 YE1ARS OF *MARSILEA VESTITA* IN PULASKI COUNTY, ARKANSAS.**

2:00 J.L. Farris[1], J.T. Knight[2], C.D. Milam[1], F. Buzen[2], and J. F. Nix[3], [1]Ecotoxicology Research Facility, Arkansas State University, Jonesboro, AR 72467, [2]Biology Department, Ouachita Baptist University, Arkadelphia, AR 71998, [3]The Ross Foundation, Arkadelphia, AR 71923. **IN STREAM MONITORING OF SEDIMENTS AND WATER IN THE LOWER OUACHITA RIVER FOR SITE IMPACT TO AQUATIC BIOTA.**

2:15 Break

2:45 **Robin G. Roggio[1], K. F. Steele[2], P. F. Vendrell[2], and M. A. Nelson[2], [1]Department of Geology, University of Arkansas, 113 OH, Fayetteville, AR 72701, [2]Arkansas Water Resource Center, University of Arkansas, 113 OH, Fayetteville, AR 72701. **EFFECTS OF AGRICULTURAL PRACTICES ON WATER QUALITY AND NUTRIENT TRANSPORT IN TWO SMALL WATERSHEDS, NORTHWESTERN, ARKANSAS.**

3:00 **Demetra Salisbury and Ralph K. Davis, Department of Geology, 118 Ozark Hall, University of Arkansas, Fayetteville, AR 72701. **A COMPARISON OF WATER SAMPLE COLLECTION METHODS.**

3:15 **J.W. Bowers, L.M. Cooksey, Department of Biological Sciences, Arkansas State University, State University, AR 72467 and L. R. Hilburn, Black River Technical College, Pocahontas, AR 72455. **MORPHOLOGICAL COMPARISON OF FIVE AMBYOMMA (ACARINA: IXODIDAE) SPECIES IN THE UNITED STATES.**

3:30 Shelly Pfitzner and David Jamieson. Department of Biological Sciences, Arkansas State University - Newport, Newport, AR 72112. **THE COLONIZATION OF AN OZARK CITY BY THE ASIAN TIGER MOSQUITO (*AEDES ALBOPICTUS*).**

3:45 George L. Harp, Department of Biological Sciences, Arkansas State University, State University, AR 72467. **DRAGONFLIES (ODONATA) OF THE TROPICAL DRY FOREST: I. COSTA RICA.**

1:30 **Chaojie Zhang and Philip R. Mayeux. Department of Pharmacology and Toxicology, University of Arkansas for Medical Sciences, Little Rock, AR 72205. **ANGIOTENSIN II SIGNAL ACTIVATES THE NO-cGMP PATHWAY IN RAT PROXIMAL TUBULES.**

1:45 **Dan C. Phan and Bruce W. Newton. Department of Anatomy, University of Arkansas for Medical Sciences, Little Rock, AR 72205. **THE DISTRIBUTION OF CHOLECYSTOKININ-8 AFFERENTS SURROUNDING LUMBOSACRAL AUTONOMIC NEURONS IS SEXUALLY DIMORPHIC AND ALTERED BY LACK OF ANDROGEN RECEPTORS.**

2:00 **D. Bowman, J. N. Pasley, M.E. Soulsby, and P. Chowdhury, Department of Physiology and Biphysics, University of Arkansas for Medical Sciences, Little Rock, AR 72205. **ISOLATION AND CHARACTERIZATION OF A CYTOSOLIC NICOTINE BINDING PROTEIN IN ISOLATED PANCREATIC ACINI.**

2:15 Break

2:45 S. T. Miller, S. S. McCullough, P. Chowdhury, and G. T. Blevins, Jr. Department of Physiology and Biophysics, University of Arkansas for Medical Sciences, Little Rock, AR 72205. **ALTERED CCK RECEPTOR BINDING IS ASSOCIATED WITH THE DECREASED RESPONSIVENESS AND SENSITIVITY OF PANCREATIC ACINI FROM COPPER DEFICIENT RATS TO CCK8.**

3:00 *Brad A. Clark and Steven W. Runge, Department of Biology, University of Central Arkansas, Conway, Arkansas 72035. **DIFFERENTIAL GENE EXPRESSION IN C3H-10T1/2 CELLS UNDERGOING APOPTOSIS DUE TO INTRACELLUAR ACIDIFICATION.**

3:15 *Bruno van Swinderen[1], Russell Roberson[2], Randall Kopper[2] and Mike Crower[1]. [1]Department of Anesthesiology, Washington University School of Medicine, St. Louis, MO 63110. [2]Hendrix College, Conway, AR 72032. **G PROTEINS AND CALCIUM CHANNELS AFFECT HALOTHANE SENSITIVITY IN *CAENORHABITS ELEGANS*.**

3:30 *Kim Watkins, Benjamin Hohoabu, and Dr. Richard Walker. Department of Chemistry and Physics, University of Arkansas at Pine Bluff, Pine Bluff, AR 71611. **EFFECT OF HYDROXYPROPYL-β-CYCLODEXTRIN ON THE ANORECTIC ACTIVITY OF (-)-EPHEDRINE AND ITS PRODRUG IN RATS.**

PAPER SESSIONS

Biomedical Science

Location: EDII Bldg., Room G110

Chairperson: Dr. Tom Kelly, University of Arkansas for Medical Sciences
Dr. Dennis Baeyens, University of Arkansas at Little Rock

Time Topic

1:15 **L. C. Maddox, P.D. Walker, and P.R. Mayeux. Departments of Pharmacology and Toxicology, and Pathology, University of Arkansas for Medical Sciences, Little Rock, AR 72205. **THE ROLE OF INDUCIBLE NITRIC OXIDE SYNTHASE DURING RENAL ISCHEMIA-REPERFUSION INJURY.**

CHEMISTRY I

Location: EDII Bldg., Room B107

Chairpersons: Dr. Cesar Compadre, University of Arkansas for Medical Sciences
Dr. Richard Walker, University of Arkansas at Pine Bluff

Time Topic

1:15 *James L. Sheets[1], Sarah Whitfield[1], Ali U. Shaikh[2], J.P. Freeman[3], and E.K. Fifer[1], [1]University of Arkansas for Medical Sciences, Little Rock, AR 72205, [2]University of Arkansas at Little Rock, Little Rock, AR 72204, [3]National Center for Toxicological Research, Jefferson, AR 72079. **4-NITROBIPHENYLS: SYNTHESIS AND MUTAGENICITIES.**

1:30 *M. Shane Greene, Rose McConnell, and Walter E. Goodwin, Division of Mathematics and Sciences, University of Arkansas at Monticello, Monticello, AR 71656. **WEAK ACIDS AND BASES COMMONLY USED IN NMR STUDIES: A pH COMPARISON IN WATER VERSUS DEUTERIUM OXIDE.**

1:45 *Rebecca Jackson and Michael J. Panigot. Department of Chemistry, Arkansas State University, State University, AR 72467. **STEREOSELECTIVE SYNTHESIS OF β-DEUTERATED TRYPTOPHAN FROM ASYMMETRIC REDUCTION OF INDOLE-3-CARBOX(ALDEHYDE-D) FOR USE IN SOLUTION-PHASE PROTEIN STRUCTURE DETERMINATION.**

2:00 *Kevin Lawrence and Michael J. Panigot. Department of Chemistry, Arkansas State University, State University, AR 72467. **EFFECTS OF AROMATIC RING SUBSTITUTION ON THE REARRANGEMENT OBSERVED IN THE ALKYLATION OF ACETOBROMOGLUCOSE WITH BENZYL GRIGNARD REAGENTS.**

2:15 Break

2:45 *Beniamin Hohoabu, Kim Watkins, Dedrick Hayes, Dr. Ray Bakhtiar, and Dr. Richard Walker. Department of Chemistry and Physics, University of Arkansas at Pine Bluff, Pine Bluff, AR 71611. **EFFECT OF CYCLODEXTRINS ON PRODRUG STABILITY.**

3:00 *Bobby L. Barker, Rose McConnell, Walter E. Goodwin, Division of Mathematics and Sciences, University of Arkansas at Monticello, Monticello, AR 71656. **MOLECULAR MODELING INVESTIGATION OF 3-SUBSTITUTED POLYFURAN WITH AND WITHOUT CROSS-LINKING.**

3:15 *Justin Scarbrough and Michael J. Panigot. Department of Chemistry, Arkansas State University, State University, AR 72467. **STEREOSELECTIVE SYNTHESIS OF β-DEUTERATED LEUCINE FROM ASYMMETRIC REDUCTION OF ISOBUTYR(ALDEHYDE-d) FOR USE IN SOLUTION-PHASE PROTEIN STRUCTURE DETERMINTATION.**

PHYSICS/PHYSICAL SCIENCE I

Location: EDII Bldg., Room G137

Chairpersons: Dr. Robert Engelken, Arkansas State University
Dr. W. J. Braithwaite, University of Arkansas at Little Rock

Time	Topic

1:00 *Michael Gericke, Philipos C. Loizou, and Donald C. Wold, Department of Physics and Astronomy, University of Arkansas at Little Rock, Little Rock, AR 72204. **LINEAR TRANSFORMATIONS FOR VOWEL CLASSIFICATION.**

1:15 *Michael Buck, Dr. Robert Engelken, C. Workman, A Thapa, and C. Edrington, Department of Engineering, Arkansas State University, State University (Jonesboro), AR 72467. **INDIUM-TELLURIUM COMPOUNDS ELECTROPLATED FROM MOLTEN SALT BATHS.**

1:30 *Jedediah J. Young, S.N. Yedave, and A.P. Malshe. Materials and Manufacturing Research Laboratory, Department of Mechanical Engineering, University of Arkansas, Fayetteville, AR 72701. **THE NEXT GENERATION OF INFLATABLES FOR SPACE APPLICATIONS.**

1:45 *R. Engelken, T. Jakobs, B. Johnson, C. Workman, M. Buck, A. Thapa, and C. Edrington, Optoelectronic Materials Research Laboratory, Arkansas State University, Jonesboro, AR 72467. (Mr. Jakobs is with InvoTek, Inc. of Alma, AR.) **PHOTOCONDUCTANCE AND OPTICAL ABSORPTION IN In_2S_3 FILMS.**

2:00 Julie T. Nguven, W.J. Braithwaite, University of Arkansas, Little Rock AR 72204 and Edwin S. Braithwaite, Science and Mathematics, Cedarville College, Cedarville, Oh 45314. **MONTE CARLO: SAMPLING THE SPACE AND ALTERNATE FORMULATIONS.**

2:15 *Al Thapa, Dr. R. Engelken, M. Buck, C. Workman, C. Edrington, and T. Jakobs Department of Engineering, Arkansas State University, State University (Jonesboro), AR 72467. (Mr. Jakobs is with InvoTek, Inc. of Alma, AR.) **IMPROVEMENTS IN PHOTOCONDUCTIVITY IN LARGE AREA Ag_2S FILMS.**

2:30 Break

3:00 *Trisha Crabill and Edmond W. Wilson, Jr., Department of Physical Science, Harding University, Searcy, AR 72149-0001. **CONSTRUCTION OF A NEAR INFRARED DIODE LASER SPECTROPHOTOMETER.**

3:15 *Clayton Workman, Dr. Robert Engelken, C. Edrington, M. Buck, and A. Thapa, Department of Engineering, Arkansas State University, State University (Jonesboro) AR 72467 **IMPROVEMENT IN THE ELECTROPLATING OF $CuInS_2$.**

3:30 *Shane M. Doss and Mostafa Hemmati. Physical Science Department, Arkansas Tech University, Russellville, AR 72801. **SPEED CUT-OFF POINT FOR ANTIFORCE WAVES.**

3:45 William C. Hall, Sue Ellen McCloskey and Wilfred J. Braithwaite, Department of Physics and Astronomy, University of Arkansas at Little Rock, Little Rock, AR 72204. **NEAR SINGULARITIES IN WEIGHTED MONTE CARLO CALCULATIONS.**

PHYSICS/PHYSICAL SCIENCE I

Location: EDII Bldg., Room G137

Chairpersons: Dr. Robert Engelken, Arkansas State University
Dr. W. J. Braithwaite, University of Arkansas at Little Rock

Time	Topic

8:30 *Holly Sawyer and Edmond W. Wilson Jr., Department of Physical Science, Harding University, Searcy, AR 72149-0001. **TROPOSPHERIC LIFETIME OF CYCLOPROPANE.**

8:45 *Philip Williams, Tony Bednar, Eric Barnett, and S.W. Reeve. Department of Chemistry, Arkansas State University, State University, AR 72467. **INTERFACING AN INFRARED DIODE LASER SPECTROMETER WITH LABVIEW.**

9:00 *Kathy Herrin and Edmond W. Wilson, Jr., Department of Physical Science, Harding University, Searcy, AR 72149-0001. **TROPOSPHERIC LIFETIME OF HYDROFLUROCARDONS.**

9:15 Cheryl L. Fossler, Frank L. Setliff, and Ali U. Shaikh. Department of Chemistry, University of Arkansas at Little Rock, Little Rock, AR 72204. **ANALYSIS OF A MIXTURE OF DIHALONICOTINIC ACIDS BY GC AND GC-MS.**

9:30 *Wendy L. Johnson, Robert T. Swindell, and Ali U. Shaikh. Department of Chemistry, University of Arkansas at Little Rock, Little Rock, AR 72204. **SEPARATION AND QUANTIFICATION OF ISOMERIC DICHLOROBENZOIC ACIDS BY GC AND REVERSED PHASE HPLC.**

9:45 Dr. Frank L. Setliff and Leslie B. Coop. Department of Chemistry, University of Arkansas at Little Rock, Little Rock, AR 72204. **THE PREPARATION OF METHYL 5-CHLORO-6-FLUORONICOTINATE BY FLUORIDE-CHLORIDE EXCHANGE.**

10:00 Break

10:30 Paul M Nave[1], Mark Draganjac[1], Bryon Ward[1], A. W. Cordes[2], and Tosha M. Barclay[2], [1]Department of Chemistry and Physics, Arkansas State University, State University, AR 72467, [2]Department of Chemistry and Biochemistry, University of Arkansas, Fayetteville, AR 72701. **LIGAND SUBSTITUTION OF $CpRu(PPh_3)_2+$ WITH TETRAHYDROTHIOPHENE. MOLECULAR STRUCTURE OF $[CpRu(PPh_3)(tht)_2]OTf$.**

10:45 Richard A. Vanderpool and Wayne T. Buckley USDA, ARS, Grand Forks, Human Nutrition Research Center, Grand Forks, ND 58203 and Agriculture, Canada, Brandon Research Station, Brandon, Manitoba Canada R7A 5Y3. **LIQUD-LIQUID EXTRACTION OF CADMIUM BY SODIUM DIETHYLDITHIO-CARBAMATE FROM BIOLOGICAL MATRICES FOR ISOTOPE DILUTION ICP-MS.**

11:00 M. A. Miah, Department of Chemistry & Physics, University of Arkansas at Pine Bluff, Pine Bluff, AR 71611. **MICROLEVEL CLIMATE CHANGE DUE TO CHANGE IN SURFACE FEATURES.**

11:15 Thomas L. Foti and George Bukenhofer, Arkansas Natural Heritage Commission, Little Rock, AR 71920. **SECTION AND SUBSECTIONS OF THE INTERIOR HIGHLANDS OF ARKANSAS AND OKLAHOMA.**

11:30 Paul D. Mixon. Department of Engineering, Arkansas State University, State University, AR 72467. **SITING HIGH VOLTAGE ELECTRICAL FACILITIES IN ARKANSAS: ENVIRONMENTAL, LEGAL, AND REGULATORY CONSIDERATIONS.**

MICROBIOLOGY

Location: EDII Bldg., Room G110

Chairpersons: Dr. Marie Chow, University of Arkansas for Medical Sciences
Dr. Scott Kirkconnell, Arkansas Tech University

Time **Topic**

8:45 *Any M. Hardwick and F. W. Speigel, Department of Biological Sciences, University of Arkansas, Fayetteville, AR 72701. **THE AMOEBA BIOTA OF PINEY DITCH SWAMP, MONROE COUNTY, ARKANSAS.**

9:00 *Nichele M. Anderson and Shelton Fitzpatrick, Department of Biology, University of Arkansas at Pine Bluff, AR 71601. **MICORORGANISMS IN COMMON PLACES.**

9:15 *Lori Sale, Tiffany Schirmer, Richard Wirges, Eric Anderson, and Dr. Scott Kirksonnell Arkansas Tech University, Russellville, AR 72801. **COLIFORM EVALUATION AND SOURCE DETERMINATION FOR THE RIVER VALLEY WATERWAYS.**

9:30 *Kristy Jones and Dr. Juneann Murphy. Departrnent of Biology, John Brown University, Siloam Springs, AR 72761, and Department of Microbiology and Immunology, University of Oklahoma Health Sciences Center, Oklahoma City Oklahoma, 26901. **IN VITRO GROWTH CHARACTERISTICS OF TWO *CRYPTOCOCCUS NEOFORMANS* ISOLATES.**

9:45 *Jeremy Alan Warford[2], Dr. Paul Hermonat[1], and Dr. Joyce Hardin[2], [1]University of Arkansas for Medical Sciences, Little Rock, AR 72205, [2]Hendrix College, Department of Biology, Conway, AR 72032. **THE UTILITY OF ADENO-ASSOCIATED VIRUS AS A TRANSDUCTION VECTOR.**

10:00 Break

10:30 **Allen Dye[1], James Daly[2], James Pasley[3], Carl Long[4], and David Stuckey[5], University of Arkansas for Medical Sciences Department of [1]Pharmacology and Toxicology, [2]Microbiology and Irnmunology, [3]Physiology and Biophysics, [4]Arkansas State Department of Health, and [5]Arkansas Children's Hospital, Little Rock, AR 72205. **GIARDIASIS IN ARKANSAS: AGE DISTRIBUTION AND THE GIARDIA SEASON.**

10:45 Robin Jordan, Rhonda Williams, Nanette Gusick, and Wayne L. Gray. Department of Microbiology and Immunology, University of Arkansas for Medical Sciences, Little Rock, AR 72205. **PATHOGENESIS OF CHANNEL CATFISH HERPESVIRUS.**

11:00 Rhonda J. Williams, Kenneth F. Soike, and Wayne L. Gray, Department of Microbiology and Immunology, University of Arkansas for Medical Sciences, Little Rock, AR 72205. **RAPID DIAGNOSIS OF SIMIAN VARICELLA USING THE POLYMERASE CHAIN REACTION.**

PHYSICS/PHYSICAL SCIENCE II

Location: EDII Bldg., Room B107

Chairpersons: Dr. Roger Hawk, University of Arkansas at Little Rock
Dr Edwin Braithwaite, Cedarville College, Cedarville, OH

Time **Topic**

8:00 Viet V. Dinh, Physics & Astronomy, University of Arkansas, Little Rock, AR 72204 and Edwin S. Braithwaite, Science and Mathematics, Cedarville College, Cedarville, OH 45314. **MONTE CARLO VS ANALYTICAL OR CLOSED FORM (PROBLEM) SOLUTIONS.**

8:15 Sayed Saiful Afsar Al-Mahmood, H. A. Naseem, and W. D. Brown, Department of Engineering, University of Arkansas, Fayetteville, AR 72701. **EFFECT OF SUBSTRATE TEMPERATURE/FILM THICKNESS ON ELECTRICAL /OPTICAL PROPERTIES OF CDS FILM AND IMPROVEMENT OF FILM QUALITY BY HEAT /$CDCL_2$ TREATMENT.**

8:30 W. J. Braithwaite, Physics and Astronomy, University of Arkansas, Little Rock, AR 72204 and E.S. Braithwaite, Science and Mathematics, Cedarville College, Cedarville, OH 045314. **CONTINUOUS MONITORING OF STAR'S MAIN TIME PROJECTION CHAMBER.**

8:45 M. A. Miah, Department of Chemistry & Physics, University of Arkansas at Pine Bluff, Pine Bluff, AR 71611; K. Nagata, Faculty of Engineering, Tamagawa University, Machida, Tokyo, Japan; T. Kohno, Instructor of Physical & Chemical

Research, Wako, Saitama, Japan; H. Murakami and A. Nakamoto, Department of Physics, Rikkyo University, Nishi-Ikebukuro, Tokyo, Japan; J. Kikuchi and T. Doke, Science & Engineering Research Lab, Waseda University, Shinjuku, Tokyo, Japan; and N. Hasebe, Faculty of General Education, Ehime University, Matsuyama, Ehime, Japan. **ANALYSIS OF OLD SATELLITE DATA: EXOS-C'S OBSERVATION OF OFF-EQUATORIAL GLOBAL ZONES OF ENERGETIC PARTICLE PRECIPITATION.**

9:00 *Candace Lindsey, Anthony Bednar, Philip Williams, Eric Barnett, and S.W. Reeve, Department of Chemistry, Arkansas State University, State University, AR 72467. **INFRARED LASER SPECTROSCOPY OF JET COOLED MANGANESE PENTACARBONYL HALIDES.**

9:15 *Anthony Bednar, Candace Lindsey, Philip Williams, Eric Barnett, and S.W. Reeve. Department of Chemistry, Arkansas State University, State University, AR 72467. **INFRARED LASER SPECTROSCOPY OF JET COOLED MOLECULES.**

9:30 Break

10:00 **Timothy W. Wofford and Dr. Roger M. Hawk, Department of Applied Science, University of Arkansas at Little Rock, Little Rock, AR 72204. **A STUDY OF RUTHENIUM OXIDE COATING FOR USE IN THIN FILM CAPACITORS.**

10:15 **Dr. Al Adams, Dr. Keith Hudson, Richard Homard, Applied Science, University of Arkansas at Little Rock, Little Rock AR 72204. **LOW POWER DIODE LASERS FOR RAMAN SPECTROSCOPY.**

10:30 **F. A. Khalifa, M. S. Haque, H. A. Naseem, and W. D. Brown, Department of Electrical Engineering, University of Arkansas, Fayetteville, AR 72701. **CHARACTERIZATION OF POLYSILICON FABRICATED BY LOW TEMPERATURE METAL INDUCED CRYSTALIZATION OF AMORPHOUS SILCON.**

10:45 H.A. El-Jammal, M. S. Haque, H. A. Naseem, and W. D. Brown, Department of Electrical Engineering, University of Arkansas, Fayetteville, AR 72701. **PN JUNCTION DEVICES FABRICATED USING LOW TEMPERATURE METAL INDUCED CRYSTALLIZATION OF AMORPHOUS SILICON.**

11:00 E. S. Braithwaite, Science and Mathematics, Cedarville College, Cedarville, OH 45314, Christine A. Byrd and W.J. Braithwaite, University of Arkansas, Little Rock, AR 72204. **EFFECTS ON ISOTROPIC DATA OF FINITE SAMPLING & SYSTE1WAIC ERRORS.**

11:15 Sue Ellen McCloskey, William C. Hall and Wilfred J. Braithwaite, Department of Physics and Astronomy, University of Arkansas at Little Rock, Little Rock, AR 72204. **APPLYING BINOMIAL STATISTICS TO WEIGHTED MONTE CARLO PROBLEMS.**

11:30 Mark Anthony Conti, Charles R. Bowlus, Department of History and W.J. Braithwaite, Department of Physics and Astronomy, University of Arkansas, Little Rock, AR 72204. **EVIDENCE FOR MASS PRODUCTION OF SWORDS IN THE TENTH CENTURY.**

ZOOLOGY

Location: EDII Bldg., Room G137

Chairpersons: Dr. Stan Trauth, Arkansas State University
Dr. Gary Heidt, University of Arkansas at Little Rock

Time **Topic**

8:15 **Shawn M. Cochran, Vernon Hoffman, V.R. McDaniel, and J.D. Wilhide. Department of Biology, Arkansas State University, State University, AR 72467. **PRELIMINARY SURVEY OF BAT SPECIES ABUNDANCE AND DIVERSITY IN A SOUTHERN BOTTOMLAND HARDWOOD SWAMP.**

8:30 Daniel R. England and David A. Saugey. Department of Biology, Southern Arkansas University, Magnolia, AR 71753, and United States Forest Service, Ouachita National Forest, Jessieville, AR 71949. **RADIOTELEMETRY STUDY OF *CORYNORHINUS RAFINESQUII* IN SOUTHERN ARKANSAS.**

8:45 Douglas A. James, Department of Biological Sciences, University of Arkansas, Fayetteville, AR 72701. **QUANTIFICATION OF THE INCREASE IN NUMBER OF AVIAN SPECIES WITH CORRESPONDING INCREASE IN HABITAT COMPLEXITY.**

9:00 **Brady Baker, V. R. McDaniel, J.D. Wilhide, and Betty G. Crump[1]. Arkansas State University, Department of Biology, AR72467, [1]Ouachita National Forest, Caddo Ranger District, AR71943. **USE OF ARTIFICIAL ROOST STRUCTURES BY BATS IN THE OUACHITA NATIONAL FOREST.**

9:15 James E. Kellum, Arkansas Forest Resources Center, School of Forest Resources, U of Arkansas at Monticello, Monticello, AR 71656, Edmond J. Bacon, Division of Mathematics and Science, U of Arkansas at Monticello, Monticello, AR 71656, Brian R. Lockhart, Arkansas Forest Resources Center, School of Forest Resources, University of Arkansas at Monticello, Monticello, AR 71656. **HERPETOFAUNAL COMPOSITION FOLLOWING COMPLETE AND PARTIAL HARVESTING IN A BOTTOMLAND HARDWOOD ECOSYSTEM.**

9:30 Stanley E. Trauth and J.D. Wilhide. Department of Biological Sciences, Arkansas State University, State University, AR 72467. **MOVEMENTS OF ALLIGATOR SNAPPING TURTLES *(MACROCLEMYS TEMMINCKII)* IN A NORTHEASTERN ARKANSAS STREAM USING RADIO TELEMETRY.**

9:45 Break

10:15 Butch E. Hamlett, Andy G. Streaker, and Stanley E. Trauth, Department of Biological Sciences, Arkansas State University, State University, AR 72467. **CAUDAL COURTSHIP GLANDS IN THE CAVE SALAMANDER, *EURYCEA LUCIFUGA* (CAUDATA: PLETHODONTIDAE).**

10:30 *Chad W. Hargrave and James E. Johnson, U.S. Geological Survey, Biological Resources Division, Arkansas Cooperative Fish and Wildlife Research Unit, University of Arkansas, Fayetteville, AR 72701. **CURRENT STATUS OF ARKANSAS DARTER *(ETHEOSTOMA CRAGINI)* AND LEAST DARTER *(ETHEOSTOMA MICROPERCA)* IN ARKANSAS.**

10:45 Donald Phillips and Thomas Nelson, Zoology Department, Eastern Illinois University, Charleston, IL 61920. **PHYSICAL CONDITION AND REPRODUCTIVE SUCCESS OF DEER ON FORT CHAFFEE.**

11:00 J. D. Wilhide, Brady Baker, V. Rick McDaniel, and Michael J. Harvey[1] Arkansas State University, Department of Biology, State University, AR 72467. Tennessee Technological University, Deparanent of Biology, Cookeville, IN 38505. **BATS OF THE OZARK NATIONAL FOREST: BUFFALO AND SYLAMORE RANGER DISTRICTS.**

11:15 David A. Saugey, Robin L. Vaughn, Betty G. Crump and Gary A. Heidt. United States Forest Services, OuachitaNational Forest, Hot Springs, AR 71902, Department of Biology, University of Arkansas at Little Rock, Little Rock AR 72204 (GAH). **NOTES ON THE NATURAL HISTORY OF *LASIURUS BOREALIS* CHIROPTERA: VESPERTILIONIDAE) IN ARKANSAS.**

11:30 J. D. Wilhide and Brady Baker, Arkansas State University, Department of Biology, State University, AR 72467. **ARKANSAS RANGE EXTENTION OF THE SEMINOLE BAT *(LASIURUS SEMINOLUS).***

POSTER SESSION

Location: EDII Bldg., Room G Concourse

Topic

#Sarah Blossom, Kathleen M. Gilbert. Department of Microbiology and Immunology. University of Arkansas for Medical Sciences, 4301 West Markham St., Little Rock, AR, 72205. **CD40 LIGAND-EXPRESSING B CELLS FROM BXSB MICE PROMOTE ANTIBODY PRODUCTION.**

#Charlotte A. Dayer, Dean Wright, Christopher Moore, and Galen R. Wenger, University of Arkansas for Medical Sciences, Department of Pharmacology and Toxicology, Little Rock, Arkansas 72205-7199. **EFFECTS OF SCHEDULES OF REINFORCEMENT AND DRUGS OF ABUSE ON SHORT-TERM MEMORY PERFORMANCE.**

#J.K. Divine, R.J. Hine, R. Hakkak, L. Dumenci; University of Arkansas for Medical Science, Department of Dietetics and Nutrition, Slot 627, Little Rock, AR 7220. **DIETARY METHIONINE AND ITS RELATIONSHIP TO PLASMA HOMOCYSTEINE LEVELS IN CHILDREN AND ADOLESCENTS.**

#Whitney A. Hayes, Jon R. Pierce, Jerry A Farris, Anne A. Grippo, Dept. Biological Sciences, Arkansas State University, State University, AR 72467. **VITELLOGENIN PURIFICATION FROM THE SLIDER TURTLES *Trachemys scripta***

#Jonathan L. Norman, Brian Bakke, David W. Paul, Department of Chemistry and Biochernistry, ChemistryBuilding, University of Arkansas, Fayetteville,AR 72701. **COMPUTER INTERFACING A WENKING POTENTIOSTAT FOR EQCM APPLICATIONS.**

#Andrew Strecker, Anne A. Grippo, Dept. Biological Sciences, Arkansas State University, State University, AR 72467; Michael E. Baker, University of California, San Diego. **DISPLACEMENT OF STEROID HORMONES FROM SEX HORMONE BINDING GLOBULIN BY PHYTOESTROGENS.**

An Infrared Diode Laser Spectrometer for the Study of Jet Cooled Gases

Anthony Bednar, Eric Barnett, Candace Lindsey, Trey Heath, Philip Williams
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Department of Chemistry and Physics
Arkansas State University
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Abstract

We have constructed a tunable, high resolution, infrared diode laser spectrometer and combined it with a pulsed supersonic jet expansion. A modified version of the Perry multipass cell has been incorporated into the spectrometer to increase the effective absorption path length. Performance capabilities of the spectrometer are evaluated by examining ro-vibrational spectra for the carbon monoxide molecule in the five micron region of the infrared. From these measurements, an instrumental absorption sensitivity is determined. Finally, since one of our immediate goals is the infrared study of jet cooled transition metal carbonyls, we present high resolution data obtained by entraining the vapor above a solid metal carbonyl and injecting it into the pulsed jet expansion.

Introduction

Infrared spectroscopy is a powerful method of analysis with a rich chemical history. Indeed, the application of this technique to identify functional groups in complex organic molecules by their characteristic infrared absorption band features is well known (see Silverstein et al., 1981). When a molecule absorbs an infrared photon an energy transition is induced from a rotational energy level in one vibrational state to a rotational energy level in a higher vibrational state (Atkins, 1983). In the gas phase, using an optical probe with sufficient resolution (~0.003 cm^{-1}), it is possible to quantitatively measure the rotational energy spacing within a vibrational state. The measurement and subsequent analysis provides a plethora of fundamental information about the chemical and physical bonding interactions in the molecule. Details concerning molecular structure, the strength of chemical bonds, and the shape of molecular potential energy surfaces, for example, can all be extracted from the high resolution spectra (Atkins, 1983).

Over the past year, we have assembled a tunable, high resolution, infrared diode laser spectrometer at Arkansas State University and combined it with a supersonic jet expansion sample source. While this type of sample source introduces several experimental challenges, two important sensitivity improvements can be realized. Jet expansions not only provide a collision free environment to effectively isolate a gas phase molecule, they also produce rotationally cold gas samples (Levy, 1984; Miller, 1984). At typical jet temperatures (10-50 K), the lower rotational energy levels in a given vibrational state will be preferentially populated (Levy, 1984; Miller, 1984). The net result of this effect will be spectra exhibiting greater intensity and less congestion. Moreover, this cooling will be critical in extending the investigation to include larger transient molecules which typically possess smaller rotational constants and larger rotational partition functions (Bernath, 1990).

Combined infrared diode laser/supersonic jet expansion spectrometers have now been built by several research groups worldwide (see De Piante et al., 1989; Heath et al., 1991; Hu et al., 1993; Juang et al., 1992; Low et. al., 1996; McKellar et al., 1991; Schuder et al., 1991; Sharpe et al., 1988; Takami et al., 1986; Xu and McKellar, 1996). While we relied heavily on these instrumental descriptions during the construction phase of this work, we included several modifications (driven primarily by economic factors) in our spectrometer. The modifications have been evaluated through a series of diagnostic experiments performed to test the capabilities of our spectrometer. We were particularly interested in determining the sensitivity of our instrument since the success of future projects involving gas phase free radicals will depend on our ability to see small quantities of molecules. For the detection limit, or sensitivity determination, various isotopes of carbon monoxide ($^{12}C^{16}O$, $^{13}C^{16}O$, and $^{12}C^{18}O$) were observed in natural abundance. Carbon monoxide has been extensively studied in the microwave and infrared regions and so represented a natural choice for tuning up the instrument. In fact, a complete listing of every known carbon monoxide absorption in the five micron region can be downloaded from the National Institute of Standards and Technology (NIST) website (see http://physics.nist.gov). The table has several hundred entries and includes fundamental and hot band transi-

tions for several isotopic species. The NIST table has proven invaluable during these diagnostic experiments because gas cell spectra have been recorded that contain absorption lines for three different isotopic species. Here we present experiments performed to determine an instrumental absorption sensitivity and a detailed description of modifications made during the construction of the spectrometer.

and fine tuning mechanism for wavelength selection. Modulation of the laser can be selected manually through the controller. For example, a chopped modulation is used to monitor signal strength during optical alignment. With an externally applied ramp modulation the laser can be scanned through various regions in the infrared at rates of up to 0.2 wavenumbers (cm^{-1}) per millisecond. The rapid scan infrared diode laser instruments described in the litera-

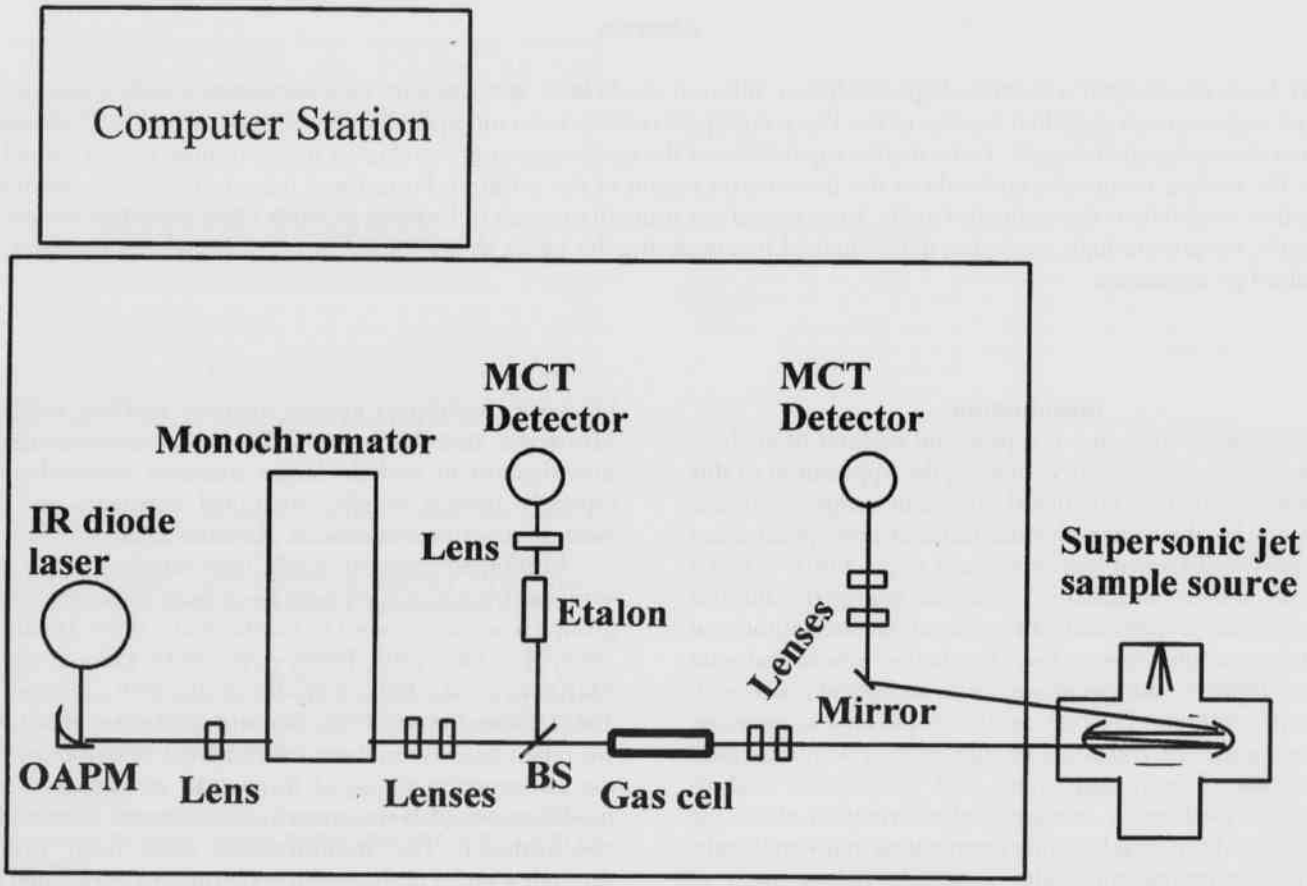

Fig. 1. Schematic of our infrared diode laser spectrometer.

Materials and Methods

Figure 1 is a diagram of our instrument. The boxed area is a laser table of dimensions 122 cm wide x 182 cm long x 30 cm thick. Lead-salt tundable diode lasers (TDLs) are housed in a Laser Photonics, Inc. L5737 liquid nitrogen dewar that maintains the temperature of the diode at 80-120 K. The dewar can hold up to four TDL's, although at the moment only two are mounted for use. A Laser Photonics, Inc. L5830 laser controller provides manual adjustment of temperature and current to the diode which acts as a coarse

ture generally utilize a waveform generator to produce the voltage ramp to scan the laser and a delayed pulse generator to control the pulse driver. While these sophisticated electronic devices provide the required timing to synchronize a laser scan ramp with a sample gas pulse in a jet expansion (see below), they are quite expensive. For example, a Stanford Research Systems waveform generator with computer communication capability costs ~$1500. A Stanford Research delayed pulse generator is ~$4000. We have been able to achieve the same synchronization capability with LabVIEW software. Although we are using the

National Instruments full development LabVLEW package (academic price $1300), the instrument synchronization could, in principle, have been controlled with the $50 LabVIEW Student Edition package. A detailed description of the software we developed to provide the ramp modulation is given in a second paper submitted to these proceedings (Williams et al., accepted).

The beam of radiation produced by a TDL possesses an elliptical crosssection that diverges rapidly. To combat this problem, an aluminum Off-Axis Parabolic mirror (OAPM) is used to collimate the beam and direct it at a right angle towards a CVI Laser 482 DigiKrom 0.5 meter triple grating monochromator used for rough wavelength selection. At the time of purchase, CVI was offering a 0.5 m monochromator for the cost of a 0.25 m monochromator (this sale represents a savings of ~$5000). Continuing with a description of the experiment, the radiation is focused into the monochromator with a 250 millimeter (mm) calcium fluoride (CaF_2) lens. CaF_2 lenses are required in the mid IR because glass lenses do not transmit infrared radiation above 2 microns (μm). A second set of lenses is positioned immediately after the monochromator to collimate and focus the beam onto an uncoated nitrocellulose beam splitter. The beam splitter directs 8% of the radiation through a 2.54 cm thick piece of solid germanium which serves as an étalon. After exiting the étalon, the radiation is focused onto a Grasby mercury cadmium telluride (MCT) detector with a CaF_2 f/2 lens. The étalon possesses a free spectral range of 0.048 cm^{-1} and essentially creates an interference wave in the infrared signal. Maxima in the interference signal are spaced precisely at 0.048 cm^{-1}. Thus, the étalon signal is used for relative calibration. Absolute calibration of the infrared radiation is accomplished with a gas cell containing a reference gas with known spectral lines for the infrared region being examined.

The infrared radiation transmitted through the beam splitter constitutes the signal channel and is focused with a 500 mm focal length CaF_2 lens into the supersonic jet chamber. By the way, all of the CaF_2 lenses were purchased from International Scientific Products at a substantial savings (>$100 per lens in some cases depending upon focal length)

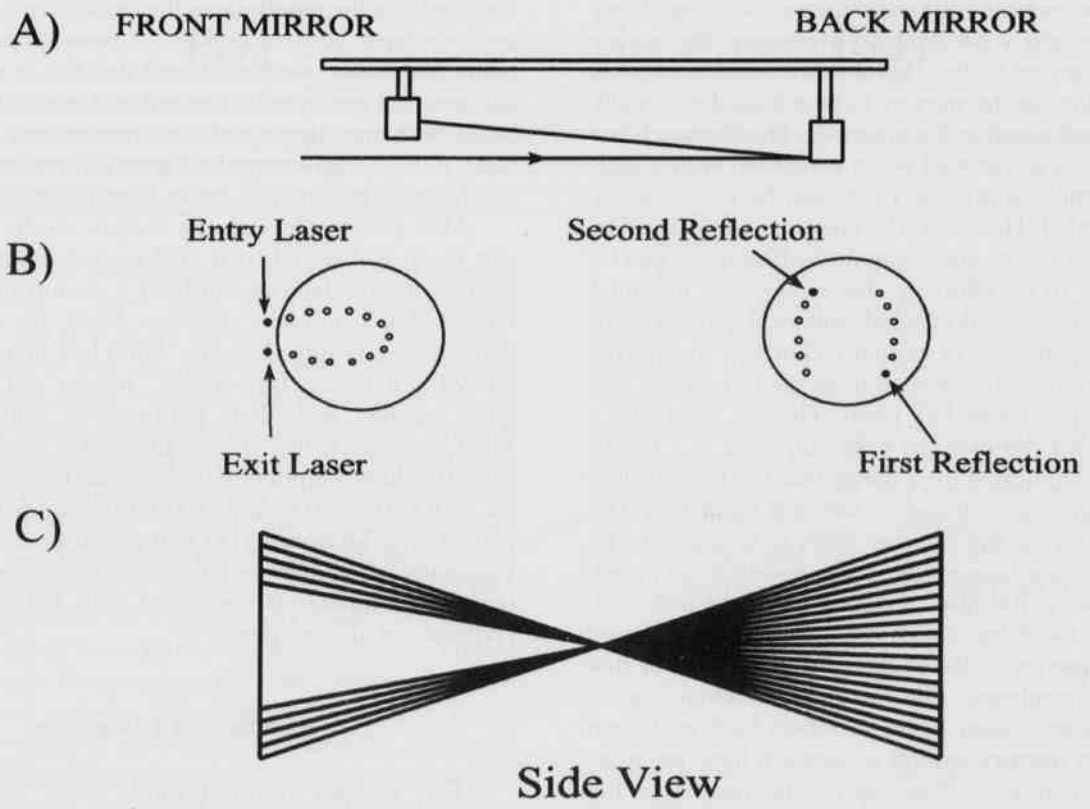

Fig. 2. Schematic showing A) how the two spherical mirrors are mounted on the ring stand rod relative to one another; B) dot patterns observed on each multipass mirror with the HeNe laser; and C) multipass pattern observed when viewing HeNe laser from a side viewport.

compared with equivalent optics from Oriel, Optics for Research, or Rocky Mountain Instruments. The chamber is a stainless steel six way cross with 15 cm diameter tubes from Kurt J. Lesker, Inc. . The chamber is evacuated with a CenCo 15 cm diffusion pump backed by a 500 liter per minute Welch model 1397 mechanical pump. The chamber can be isolated from the pump with a 15 cm gate valve and a Varian model 326 cryotrap is used to prevent back-streaming into the chamber. Parenthetically, both vacuum pumps, as well as the cryotrap, were purchased used from HK Equipment, again at a significant reduction in price (~40% of cost new). Without the cryotrap, the oil used for the diffusion pump would eventually coat the walls of the chamber and the multipass assembly located inside it. A General Valve Series 9 pulse valve mounted on one chamber flange creates the supersonic jet. The pulsed valve together with a pulse driver comprise the General Valve Iota One molecular beam system. The pulse driver can be operated manually with controls on its front panel or remotely through software.

Our multipass cell is a low cost version ofthe Perry cell (Kaur et al., 1990). While the original Perry cell utilized off-the-shelf commercial mirrors, the mirrors were mounted on kinematic mirror mounts with translation control capability in addition to x and y tilt control. Moreover, the mirror mounts were attached to the chamber flanges via vacuum feedthroughs allowing the mirrors to be adjusted externally once they were mounted in the chamber. The Perry cell is a proven design that works well when combined with a molecular beam sample source and can also be conveniently realigned as needed. However, the components, particularly the kinematic mounts and vacuum feedthroughs, can be quite expensive. In an effort to save money, we mounted two 2.54 cm diameter, gold-coated, spherical mirrors from Edmund Scientific in a set of standard Thorlabs, Inc. mirror mounts which in turn are attached to an aluminum rod (see Fig. 2) with two flex frame ball joints. The rod is actually a 1.25 cm ring stand rod that has been cut down to a length of~25 cm and is mounted on a flange that has been drilled and tapped to the same thread as the ring stand rod. The mounting location on the six way cross is arranged to be perpendicular to the flange where the nozzle is mounted. The mirrors have a 100 mm radius of curvature with a 50 mm focal point. Gold has a high reflectivity in the infrared region and is superior to the standard silver coated or first surface aluminum mirrors. The two mirrors, when aligned properly will cause a laser beam to reflect back and forth between the two mirrors around a common focal point in-between the two mirrors. If the sample is centered at the focal point of the mirrors then the path length through the sample is increased by the number of reflections or passes between the two mirrors. In our instrument, the mirrors are spaced by ~9.5 centimeters, and the "back" mirror is translated to the right of the "front" mirror (Fig. 2a). This arrangement allows the laser to miss the front mirror, reflect between the two mirrors, and then miss the front mirror exiting lower than the entry beam (Fig. 2b). The pattern created in the multipass can be examined with a helium-neon (HeNe) laser. Actually, the HeNe laser is used to align the mirrors and it is assumed the IR beam transverses the same path (Kaur et al., 1990). The number of passes are determined by counting the number of dots on the back mirror, multiplying the number of dots by two and then subtracting one.

Curiously, there are many possible dot patterns. Kaur and coworkers suggest the most desirable pattern is one that produces a parabola on each mirror (Kaur et al., 1990). The pattern is dependant on several factors including the angles of the mirrors, the angle of the entry laser, the distance that the mirrors are apart, and the location of the first reflection (or dot). We have chosen to use a slightly different dot pattern (see Fig. 2c). To achieve the multipass pattern in Fig. 2c, the first reflection must occur near the top left of the back mirror and it has to cross through the middle of the focal point. This pattern creates two vertical planes of reflections from the back mirror to the focal point. At the focal point, the planes rotate 90 degrees to create two horizontal planes coming from the parabola on the front mirror. With this pattern, we have observed up to 29 passes through the focal point. Moreover, we have found that this is one of the few patterns that generated a focused and controllable exit laser beam with no clipping of the front mirror upon exiting. Note, if the mirrors are pulled apart further, more passes can be obtained, but the exit beam becomes unfocused.

After passing through the sample via the multipass, the exit beam is directed by a gold coated flat mirror through another double lens assembly to a second nitrogen cooled Grasby MCT infrared detector. Note, the Grasby MCT detectors were approximately $600 less than the comparable MCT detectors from EG&G Judson and we have been quite satisfied with their performance. Output from the MCT detector is first passed through a Stanford Research SR560 voltage amplifier (amplifier has 6 decibel (dB) points set at 100 Hertz (Hz) and 100 kiloHertz) before being displayed on a Tektronix TDS 320 digital storage oscilloscope. Communication between the oscilloscope and a Pentium personal computer is controlled with LabVIEW software (Williams et al., accepted).

Results and Discussion

The *in-house* infrared diode laser spectrometer at Arkansas State is a versatile instrument capable of recording the vibrational spectra of gas phase molecules, free radicals, and molecular complexes at rotational resolution. The sample source for all of these molecular species is a supersonic jet expansion. To demonstrate some of the capability of our

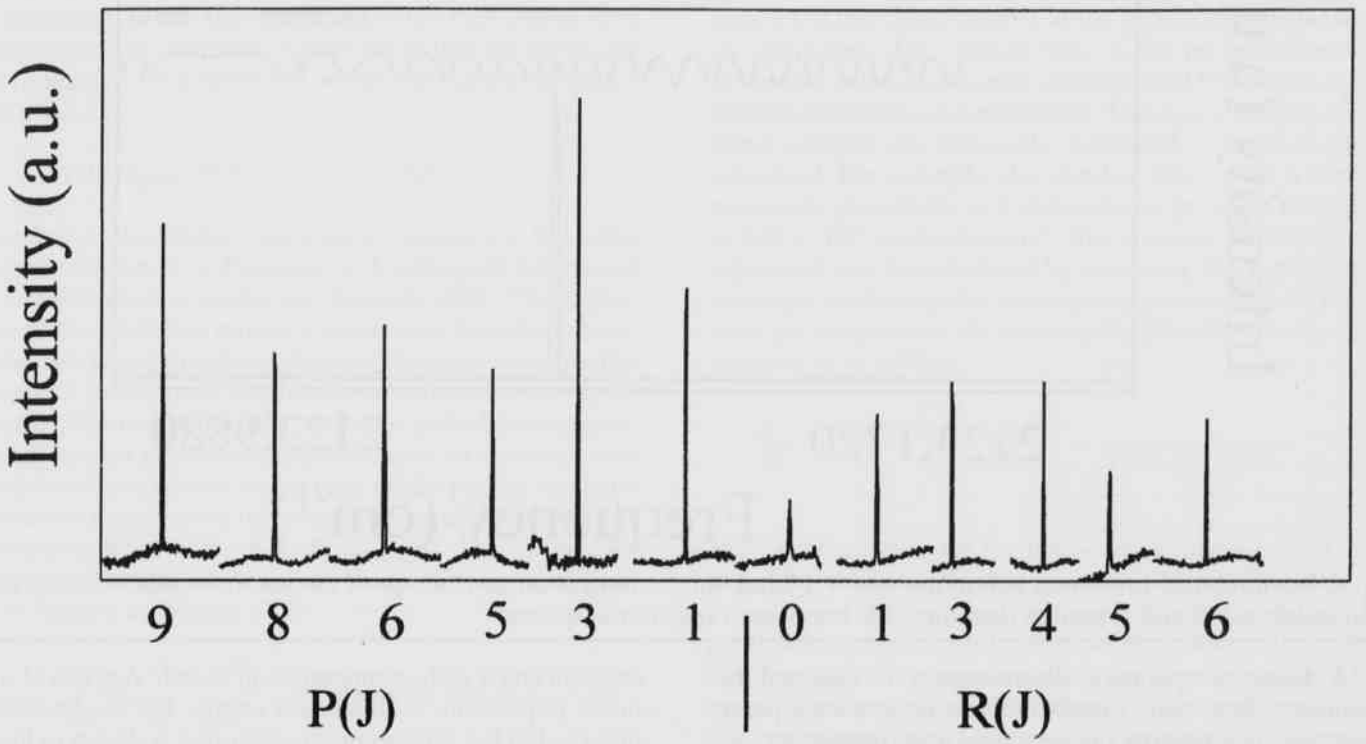

Fig. 3. Twelve rovibrational transitions of the v=0→ 1 band for carbon monoxide. The intensity of each line is plotted as a function of the P and R branch assignments.

instrument, several rovibrational transitions of carbon monoxide (v=0→ 1) have been observed and identified both in the jet and in a 10 cm gas cell. As described above, the laser is scanned over an approximately 1-2 cm^{-1} region by ramping the current. Actually, the diode laser can be continuously scanned across a longitudinal mode, which is typically 1-2 cm^{-1} in length. The modes are separated from one another by several wavenumbers and this non-continuous tunability gives rise to "snippets" of spectra. A series of twelve v=0→ 1 carbon monoxide transitions, acquired in the jet, are shown in Fig. 3. No attempt to scan a large portion of the 2100-2200 cm^{-1} region was made. We simply searched and found laser modes corresponding to known carbon monoxide frequencies. The laser power for each mode is different and the intensities of the lines in Fig. 3 have been corrected to show relative intensities. Although all the spectral lines shown have a frequency or wavelength assigned to them, the signal as it is received from the scope is time based. Frequency is assigned by examining maxima in the étalon signal which is recorded simultaneously. An expanded view of the P(5) transition with calibrated frequency is given in Fig. 4.

The rotational temperature for carbon monoxide at conditions in our jet expansion can be obtained through an intensity analysis of the individual rovibrational transitions (Steinfield, 1986). The analysis procedure involves converting the intensity of each rovibrational transition to a population by dividing the appropriate corrected intensity by the degeneracy, (2J+1), and the line strength or Hönl-London factor (Hertzberg, 1950). For rotational levels observed in P and R branch spectra, an average population for the level was calculated and used in the determination. An approximate temperature can be obtained from the expression

$$J_{max} \equiv 0.59 \sqrt{\frac{T}{B}} \qquad (1)$$

where J_{max} corresponds to the rotational level with the greatest population fraction T is the temperature in Kelvin, and B is the rotational constant in cm^{-1} (Bernath, 1995). An observed J_{max} of 3, for example, yields a rotational temperature of 50 Kelvin (K) for an expansion of neat carbon monoxide in our apparatus.

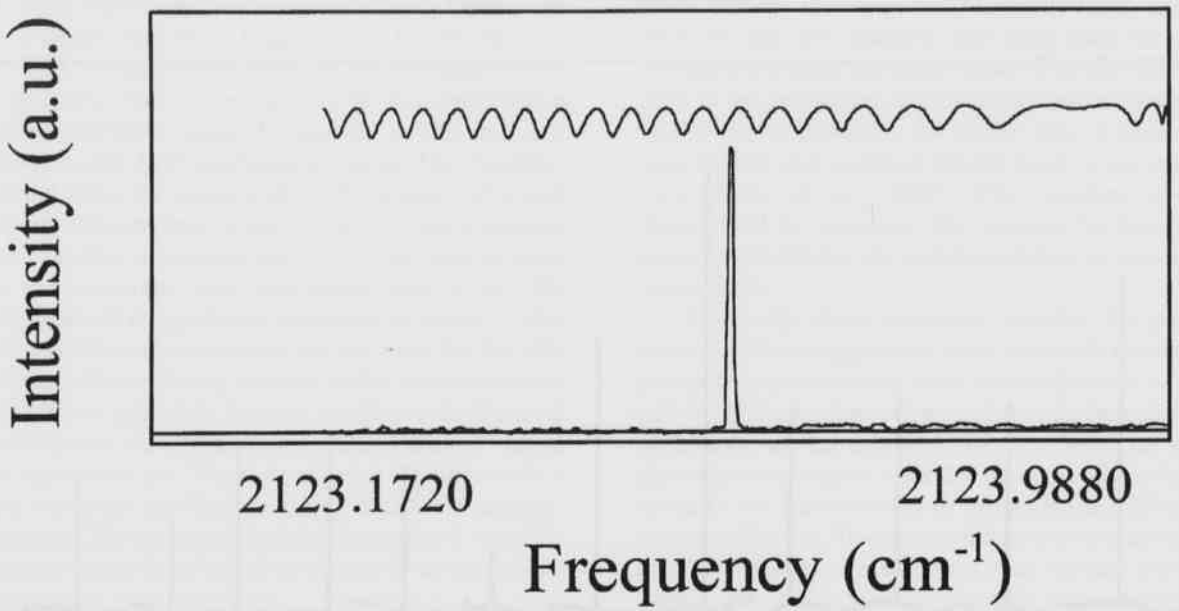

Fig. 4. Rovibrational transition, P(5) of the v=0→ 1 band, for the most abundant isotope of carbon monoxide. The top trace is an etalon signal and is used to determine the frequency range of the spectra.

A better temperature determination is obtained by assuming a Boltzmann distribution for the rotational population and then plotting the rotational level population versus the rotational energy. The points are fit to a linear expression with a slope of -1/kT, where k is the Boltzmann constant and T is the temperature in Kelvin. A graph of rotational population vs. rotational energy for the transitions observed in the supersonic jet expansion is shown in Fig. 5. We have included populations determined from both P and R branch spectra in this analysis. Rotational temperature for

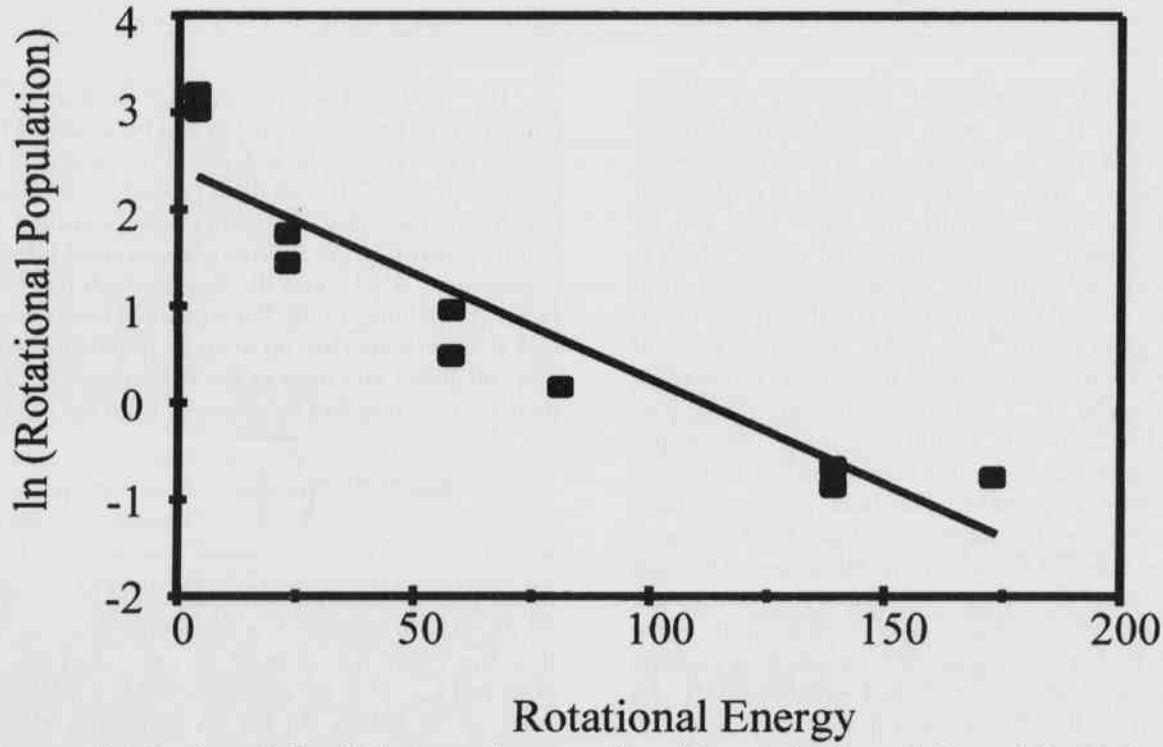

Fig. 5. Boltzmann plot showing relationship between the natural log of the rotational population and the rotational energy.

a neat carbon monoxide expansion in our jet, determined from the slope of the line, is 66 K ± 10 K.

Detection Limit Determination.--Our experiment is a typical infrared absorption experiment in that the molecular absorption can be understood within the context of Beer's Law, viz

$$I(v) = I_0(v)\, e^{-\gamma(v)L} \qquad (2)$$

where $I_o(v)$ is the incident intensity at frequency v, I(v) is the transmitted intensity at frequency v, L is the path length and $\gamma(v)$ is the absorption coefficient (Bernath, 1995). The importance of the multipass mirror arrangement described above is now clearly evident; the multipass effectively increases the absorption path length which increases the observed signal intensity. The interaction of a molecule with electromagnetic radiation can produce absorption, induced emission, and spontaneous emission if the energy of the photon happens to coincide exactly with the energy difference between two eigenstates $|m\rangle$ and $|n\rangle$, E_m-E_n, for the molecule. Neglecting spontaneous emission, the absorption coefficient can be written as (Kroto, 1992)

$$\gamma(\upsilon) = \frac{8\pi^3}{3hc}\ \upsilon\left(\frac{N_m}{g_m} - \frac{N_n}{g_n}\right) |\langle n|\mu|m\rangle|^2\ \delta(\upsilon,\upsilon_o). \qquad (3)$$

The term $\delta(v,v_o)$ in equation (3) is a line shape function, typically represented by either a Gaussian or Lorentzian function, centered at the frequency corresponding to $(E_m\text{-}E_n)/h$, v_o. The lineshape function is sensitive to a given set of experimental conditions and is molecule dependent only in terms of linewidth. The absorption coefficient, and thus the intensity of a vibrational transition, is also directly proportional to the square of the transition dipole moment, $|\langle n|\mu|m\rangle|^2$. For rovibrational transitions, the transition dipole moment is, to a first order approximation, directly proportional to $d\mu/dr$ (Bernath, 1995). The absorption coefficient is also a function of the difference in population between the two energy states, $(N_n/g_n\text{-}N_m/g_m)$. In this expression, N_i represents the number of molecules in the ground state m, the excited vibrational state n, and the degeneracy of each state is indicated by g_i. Assuming the sample is at equilibrium, the population difference can also be expressed in terms of a Boltzmann distribution, viz.

$$\frac{N_m}{g_m} - \frac{N_n}{g_n} = \frac{N_m}{g_m}\left(1 - e^{-\frac{E_m - E_n}{kT}}\right) \qquad (4)$$

The terms in the exponential denominator above are the Boltzmann constant, k, and the temperature in T. From Equation (4), the population difference will be largest, for a given rovibrational transition E_m-E_n, when kT is small. Or in other words, the population difference will be largest for samples at low temperatures, as are produced in supersonic jet expansions. The cooling effect in the jet has allowed us to observe carbon monoxide rovibrational transitions at low carbon monoxide concentrations. The concentration of gas phase samples are frequently expressed in units of molecules/cm^3. For example, the number density for a carbon monoxide gas sample at 2 atmospheres pressure and 25°C is 5.38 x 10^{19} molecules•cm^{-3}. The number density in the expansion can be calculated by assuming the expansion is isentropic and using the isentropic equation of state for an ideal gas to generate the relationship (Smalley et al., 1977; Lubman et al. 1982)

$$\left(\frac{T}{T_o}\right) = \left(\frac{P}{P_o}\right)^{\left(\frac{\gamma-1}{\gamma}\right)} = \left(\frac{\rho}{\rho_o}\right)^{(\gamma-1)} = \frac{1}{1+(1/2)(\gamma-1)M^2}. \qquad (5)$$

Here T_o, P_o, and ρ_o are the temperature, pressure and density of the gas located in the reservoir behind the nozzle, T, P, and ρ are the temperature, pressure and density for the gas in the expansion, and γ is the heat capacity ratio C_p/C_v. The quantity M in equation (5) is the Mach number (M = speed of molecules/speed of sound). Mach numbers of 50-100 (supersonic levels) are routinely achieved in jet expansions. The Mach number can be calculated from equation (6) below (Smalley et 1977)

$$M = A\left(\frac{X}{D}\right)^{(\gamma-1)} \qquad (6)$$

and the appropriate constants for argon (A= 3.26 and γ = 5/3). The quantity X in equation (6) is the distance from the nozzle (downstream) and D is the nozzle diameter. Of course, the Mach number cannot increase forever and will asymptotically approach a terminal value. In our system, for example, a terminal Mach number of ~50 is predicted based on a nozzle diameter of 0.4 mm (Smalley et al., 1977). Keep in mind, that even at high Mach numbers the molecules still travel at speeds of only ~1500 m/s. The local speed of sound however is proportional to $(T)^{1/2}$. Thus high Mach numbers are reached in the expansion because of the cooling effect of the jet rather than an increase in molecular speed.

The jet cooled spectra acquired for the detection limit determination were all obtained using one of three gas mixtures, 30%, 10%, or 5% carbon monoxide in argon, respectively. As the argon carrier represents the major component of the mixture, the calculations are approximated by using values for ρ and A appropriate for argon. For a Mach number of 37 (calculated for a position 1.5 cm downstream of the nozzle) and a reservoir number density of pot of 5 x 10^{19} molecules/cm^3, an expansion number density of ρ ~ 5 x

10^{15} molecules/cm^3 is obtained. In most cases, v=0→ 1 rovibrational transitions for the $^{12}C^{16}O$ species were observed at 100% absorbance, even for gas mixtures of 10% carbon monoxide in argon. The carbon-13 isotopic form of carbon monoxide, $^{13}C^{16}O$, has also been observed with all three gas mixtures. Figure 6 shows the v=0→ 1 R(0) line of $^{13}C^{16}O$. Given that the carbon-13 isotope is present at a 1% level in natural abundance, a number density corresponding to ~5 x 10^{12} $^{13}C^{16}O$ molecules/cm^3 is obtained with equation (5). The third isotopic form of carbon monoxide we have observed in natural abundance is $^{12}C^{18}O$. Figure 7 shows the v=0→ 1 R(1) transition recorded with a 30% gas mixture. Note, the signal to noise ratio for the absorption in Fig. 7 is ~3 or 4. We have also observed this transition with a 10% gas mixture; however, the signal to noise ratio was ~1. Oxygen-18 is present at a 0.2% level in natural abundance corresponding to a number density for the 30% gas mixture of~3 x 10^{12} molecules/cm^3.

website), a peak absorption coefficient of 0.00776 cm^{-1} is calculated for the v=0→ 1 R(0) line of $^{13}C^{16}O$. This particular transition was observed with a 5 dot pattern on the front multipass mirror. We will assume the absorption path length for one pass through the expansion is approximately 1 cm at a distance of 1.5 cm downstream of the pulsed nozzle. A peak absorption coefficient of 0.00776 cm^{-1} combined with a total absorption path length of~9 cm^{-1} will give rise to an 8% absorption. At best, the signal to noise in Fig. 6 is 25:1, suggesting the absorption sensitivity of our instrument is 0.003 with the current experimental parameters. This sensitivity level should be sufficient, however, to examine both radicals and van der Waals complexes in the jet as nominal concentrations for such species is ~10^{13} molecules•cm^{-3} (Bernath, 1990; Schuder et al., 1991).

Finally, there is some interest in comparing the absorption sensitivity of our instrument with other instruments described in the literature. In their paper describing the

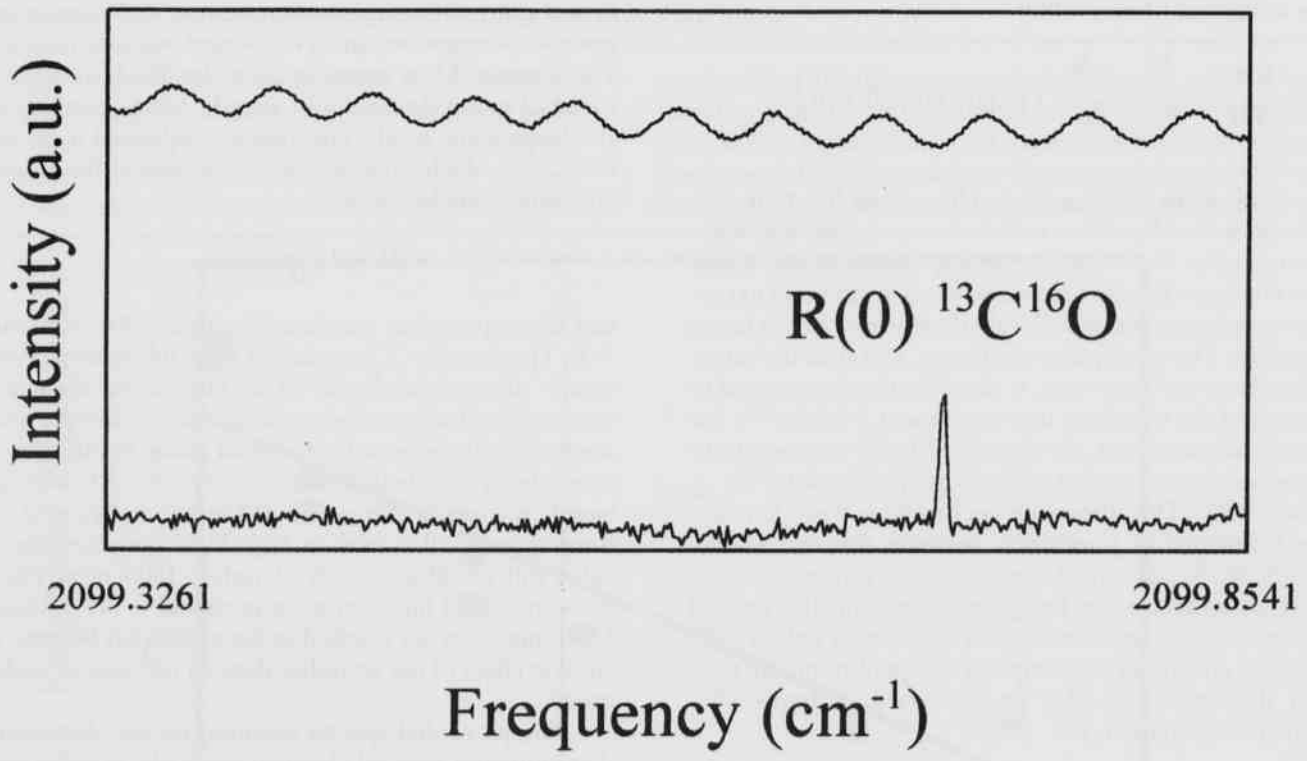

Fig. 6. Spectrum obtained with a 10% gas mixture of carbon monoxide in argon. The gas pulse has been triggered to optimize the intensity of this peak. Spectral assignment is made using a NIST table of carbon monoxide frequencies.

With the number densities in hand, we proceed with a detection limit or sensitivity calculation. Given a carbon monoxide transition moment of 0.1078 Debye (see NIST

rapid scan method for obtaining high resolution infrared spectra, De Piante and coworkers reported an instrumental sensitivity of 0.0003 (De Piante et al., 1989). The only other

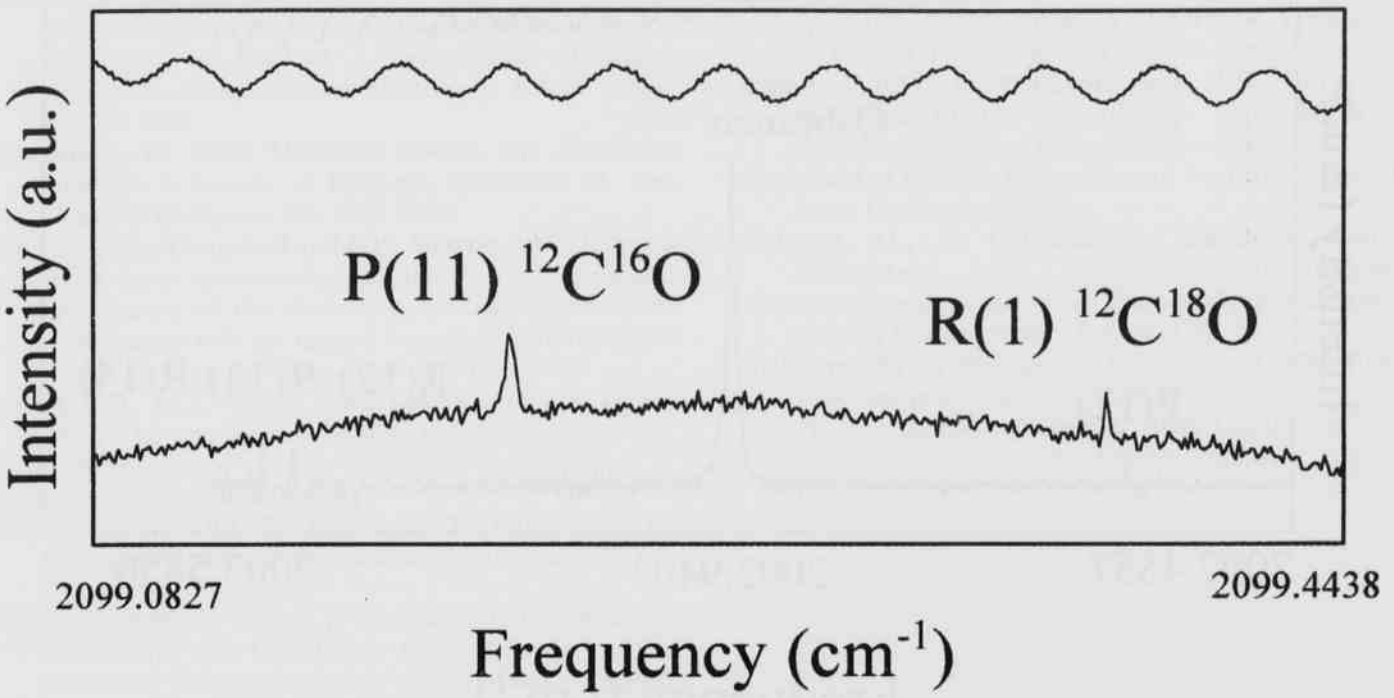

Fig. 7. Spectrum obtained with a 30% gas mixture of carbon monoxide in argon. The gas pulse has been triggered to optimize the intensity of the $^{12}C^{18}O$ peak. Spectral assignment is made using a NIST table of carbon monoxide frequencies.

reported instrumental sensitivity value for an infrared diode laser spectrometer coupled with a supersonic jet expansion that we are aware of is 0.0006 (Schuder et al., 1991). While these two values represent comparatively better figures of merit, we need to point out that both of these instruments utilize a 10 cm slit nozzle design where we have a pinhole nozzle. Slit jet nozzles offer several advantages including greater path lengths along the axis collinear with the slit and greater column densities (Nesbitt, 1994). For example, the effective path length for these two instruments is 80 cm (De Piante et al., 1989) and 24 cm (Schuder et al., 1991), respectively. Because the relationship between absorbance and path length is linear, we do plan to incorporate a slit nozzle in the future. In fact, General Valve does offer a commercial 2.54 cm slit jet nozzle for $1500 (the General Valve IOTA ONE system we are using comes standard with a pinhole nozzle). With the appropriate increases in path length, our instrument should match the absorption sensitivity reported by others.

Transition Metal Carbonyl Studies.--One of our long range goals is the high resolution infrared investigation of transition metal monocarbonyl radicals. Before we can realistically begin this work several experimental issues will need to be dealt with. We intend to produce metal monocarbonyl radicals by passing the vapor from a parent carbonyl through a gas discharge formed by attaching electrodes to the end of the pulsed nozzle. Iron monocarbonyl, for example, has been studied in the microwave region using a 2% iron pentacarbonyl in argon gas mixture (Kasai et al., 1995). Many of the metal monocarbonyl radicals we are interested in will need to be produced from solid parent carbonyl compounds. Thus, one potential experimental problem involves entraining the vapor above a solid into an argon carrier so that it can be injected into a supersonic jet/electric discharge expansion. Following the work of Paul Davies at Oxford (see for example, Burie et al., 1991), a pulsed valve with a 1.5 ml reservoir machined into the valve body has been incorporated into our supersonic jet vacuum chamber. This particular valve can also be heated with an external band heater to temperatures of ~100°C to further increase the amount of vapor pressure of the compound of interest. With this new valve, we have observed an intense Q branch and several rovibrational transitions for the v_6 band of chromium hexacarbonyl, $Cr(CO)_6$ (see Fig. 8). The spectrum in Fig. 8 represents several individual laser scans over the 2002.4557-2003.5856 cm^{-1} region, each with a dif-

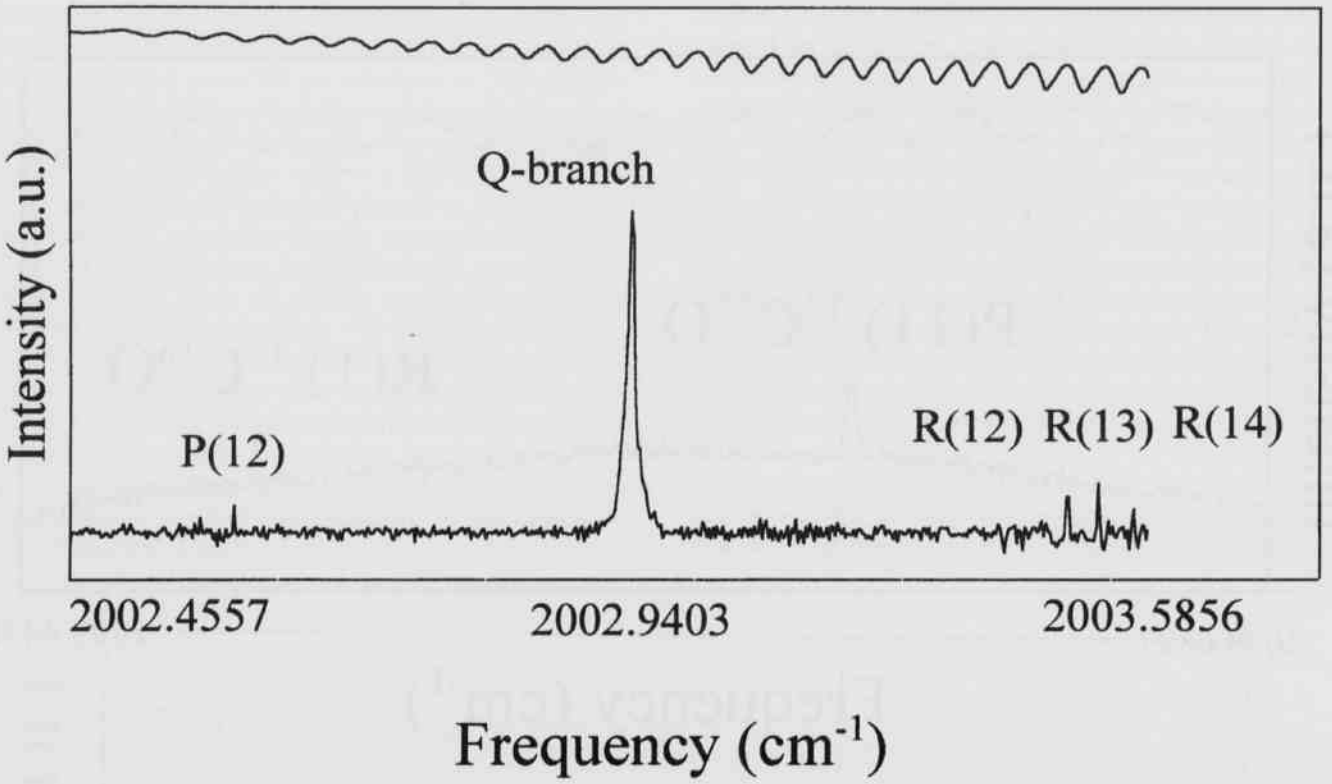

Fig. 8. Observed infrared absorption spectrum for chromium hexacarbonyl in the 5 micron region. Assignments were made following Burie, et. al., 1991.

ferent gas pulse position (in time) along an externally voltage ramp used to scan the diode laser. Thus, Fig. 8 is actually a composite obtained by summing together the individual scans and performing a baseline correction (see Williams et al., for a description of this process).

In conclusion, we have constructed an *in-house* high resolution, tunable, diode laser spectrometer from commercially available components. The spectrometer has been combined with a pulsed supersonic jet expansion to produce supercooled gas samples for spectroscopic study. Spectrometer capabilities were evaluated with a carbon monoxide gas sample and an absorption sensitivity for our instrument was determined. Continuing work will focus initially on observing high resolution spectra for several transition metal carbonyl halides. The goal here will be to develop procedures for reliably injecting vapor from the carbonyl compounds into the jet expansion.

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Continuous Monitoring of STAR's Main Time Projection Chamber

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Abstract

STAR refers to the Solenoidal Tracking instrument At RHIC (the Relativistic Heavy Ion Collider). For momenta above 500 MeV/c charged kaons are not separated from pions within STAR's Main TPC (Time Projection Chamber) by track density alone and they are poorly separated below 500 MeV/ c, even when using information from other sources like the vertex tracker. Within the TPC large numbers of kaons and pions decay into muons (and undetected neutrinos). Earlier work has shown parent pions and kaons whose decays are detected within a TPC may be distinguished uniquely from each other in a two-dimensional plot of muon-emission angle versus momentum difference (between each parent meson and its decay muon). Since pions and kaons have zero spin, each muon decay-product emerges isotropically in its parent meson's rest frame. Identification of particle type provides the parent meson's rest mass and, thus, its total energy. This means the measurement of each decay event is kinematically complete. Thus, Lorentz Transformations may be used to transform each component of the decaying muon's laboratory four-momentum into the "rest frame" of its parent meson, where the muon decay is isotropic. An aggregated plot of muon directions from many "parent rest frames" will be isotropic in each (selected) sub-volume of the TPC unless there is a problem within the TPC or in its tracking algorithms. Continuous monitoring of a TPC is possible using this subset of detected charged particles.

Introduction

Previous work using muon decays of pions and kaons (Braithwaite and Braithwaite, 1997b) has shown that by using relativistic kinematics alone (Braithwaite, 1972) parent pions and kaons whose decays are detected within a TPC (Time Projection Chamber) may be distinguished uniquely from each other. This separation is accomplished using a 2-D plot of observables within the TPC: muon-emission angle versus momentum difference (between parent meson and muon). This previous work was predicated on even earlier work (Climer et al., 1996) where mapping STAR's TPC for acceptance and efficiency was suggested using parent kaons. What was missing from this earlier work was a feasibility study of the expected quality of the separation of kaons from the much more prevalent pions using the relativistic kinematics of muon decays.

Uniquely identifying kaons and counting them measures the amount of strangeness production occurring in each central collision between two ultrarelativistic nuclei; kaon production is a direct measure of strangeness production as kaons are singly strange. This method for measuring strangeness production using charged kaon decay complements measurements of neutral kaon decay within a microTPC designed to be the component detector located closest to the collider vertex for ultra-relativistic nucleus-nucleus collisions (Braithwaite and Braithwaite, 1997a).

Despite the importance of measuring strangeness production as one signature of the onset of the Quark Gluon Plasma (Harris and Müller, 1996), the present work concentrates on a new approach to mapping STAR's Main TPC (Sauli, 1987) for acceptance and efficiency as a function of position within the TPC, using both kaons and pions. For each parent meson, the spin = 0 description of the quantum ground state requires the direction of each muon decay to be isotropic in its parent meson's rest frame. As outlined below, this feature of isotropic decay, due to the decaying pions and kaons being spin = 0 mesons, provides a new dimension in the monitoring of STAR's Main TPC.

Materials and Methods

"Kinematic trajectories" for meson decays cluster into

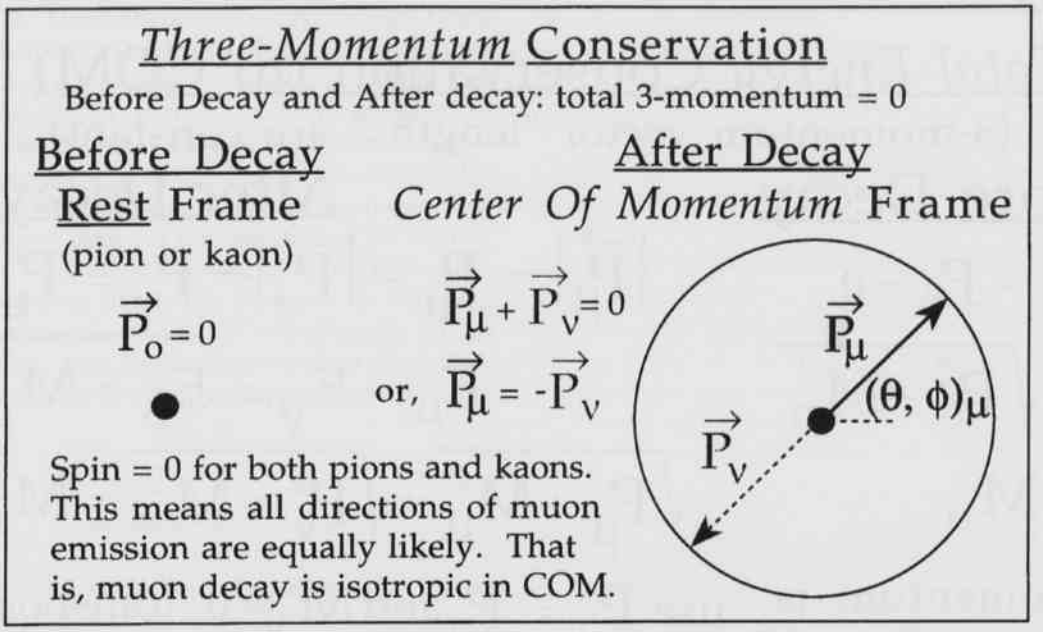

Fig. 1. Both pions and kaons decay isotropically in their respective rest frames. Each muon and unobserved neutrino has an equal but opposite 3 momentum value in the COM (center of momentum) frame, which is also the parent's rest frame.

completely separated 2-D regions of difference-momentum ⊗ muon-angle space, or $\Delta P \equiv | \vec{P}_o - \vec{P}_\mu | \cdot \text{sign}(P_o - P_\mu)$ versus θ_μ, showing kinematic separation is possible between charged kaon decays and charged pion decays. The reason for this complete kinematic separation is the much larger breakup momentum, 235.5 MeV/c in the center of momentum frame, available to each of the binary decay species (muon and neutrino) in the process of $K^\pm \rightarrow \mu^\pm + \nu$ decay. In contrast, a much smaller breakup momentum of 29.8 MeV/c is available in the center of momentum frame to each of the binary decay species (muon and neutrino) in the process of $\pi^\pm \rightarrow \mu^\pm + \nu$ decay.

Identifying which meson is decaying (kaon or pion) determines its rest mass and, thus, its total energy, so each muon decay is kinematically complete. That is, the relativistic 4-momentum (3-momentum, total-energy) is known for each parent meson as well as for its associated muon. This means each muon's 4-momentum may be transformed into the rest frame of its parent (also the μ–ν center-of-momentum frame) using measured kinematic observables (to perform the relevant Lorentz-transformations).

The idea is to aggregate muon directions from rest frames for each type of parent meson for the entire TPC or selected subgroupings. The resulting plot of data points must be isotropic unless there is an acceptance or efficiency problem within the TPC or its subgroupings. This method is also sensitive to any efficiency problem associated with the TPC's tracking algorithms (Howe et al., 1995).

Results and Discussion

Laboratory distributions for isotropic emissions of muons in the COM (Center of Momentum) Frame may be calculated using a known method for assuring spherical symmetry in the COM frame (McCloskey and Braithwaite, 1995). This method uses a triplet of numbers (x, y, z), with each randomly distributed between -1 and +1. Spherical symmetry is assured for this triplet if $x^2 + y^2 + z^2 < 1$. If not, the triplet of numbers is discarded (~48% of the time). If the inequality is satisfied, the randomly oriented position vector is renormalized to 1 and then multiplied by the known length of the muon-momentum in the COM frame as provided in Fig. 2, and each COM momentum is transformed back into the laboratory for each selected value of the parent meson's laboratory 4-momentum.

Probably a better approach is to obtain the distribution for isotropic emissions of muons in the COM Frame and analyze them there rather than comparing the muons' laboratory distribution to their calculated distribution, as transformed back into the laboratory from the COM. This is because an isotropic distribution will be a simpler distribution to analyze using standard methods such as describing the muon yields in the COM using surface-harmonic yield expansions.

Each meson is characterized by zero spin. That is, for each meson, the Quantum Mechanical description is invariant under all rotatations thus assuring each meson decay is

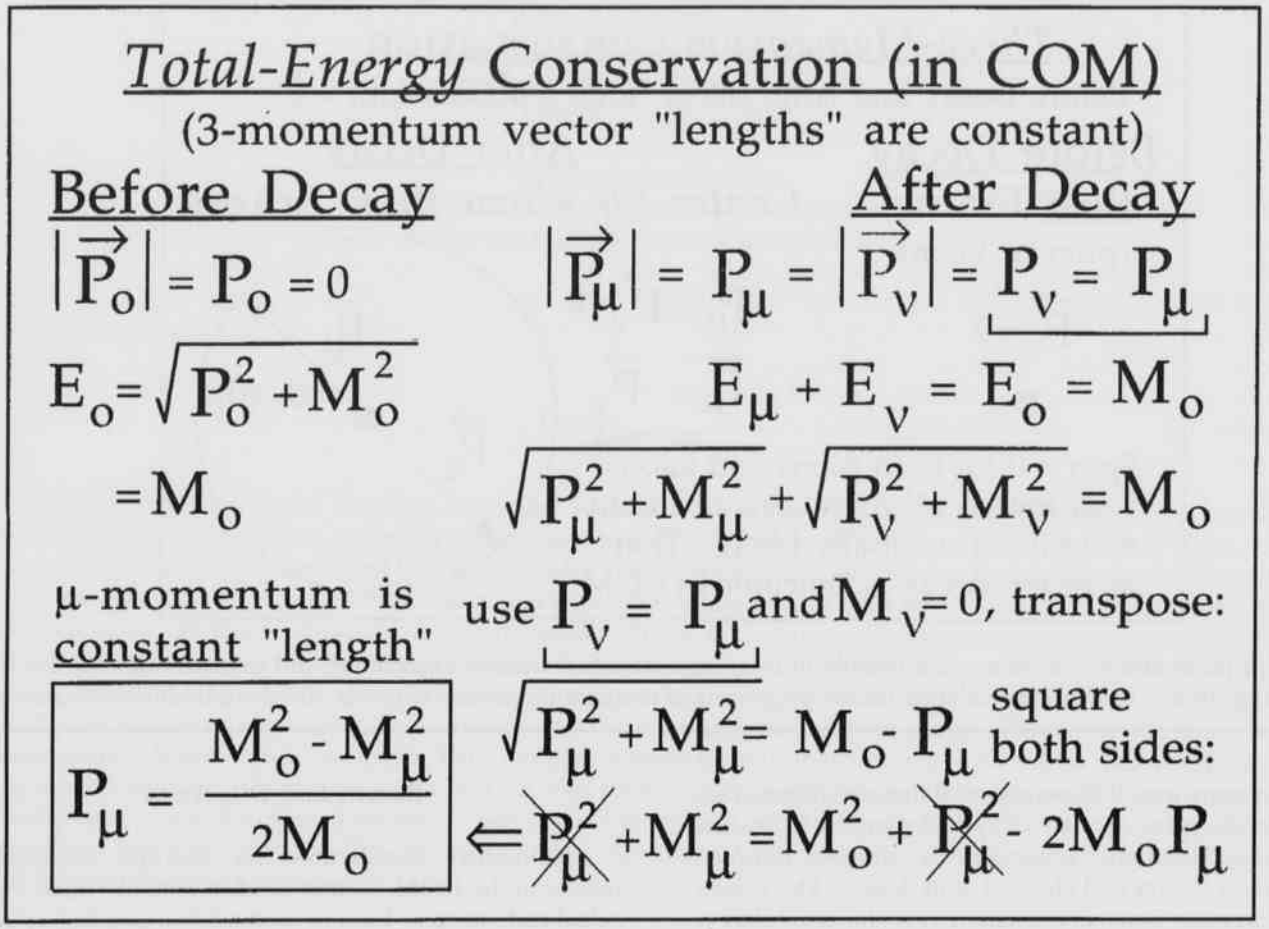

Fig. 2. Conservation of total-energy in the COM Frame predicts a constant "length" for the muon's 3-momentum. This 3-momentum vector points with equal probability in all (θ, ϕ) directions in the COM Frame.

spherically symmetric. Thus each muon decay is isotropic in the rest frame of its parent. Since there is sufficient kinematic information to transform each muon's 4-momentum into its COM frame, the known isotropy of the muon decay may be used to provide additional monitoring information for the TPC, unavailable from any other monitoring method.

Figure 1 shows three-momentum conservation in the COM (Center of Momentum) Frame, which is also the parent meson's rest frame (whether pion or kaon).

Each meson that decays into muons and neutrinos (with neutrinos undetected) does so isotropically in the parent meson's rest frame. This symmetry allows these muon decays to be used for continuous monitoring of acceptance and efficiency of STAR's Main TPC for either or both types of parent mesons (pions and/or kaons).

Since all data are finite and have systematic errors, the impact of these difficulties was examined in the COM using numerically-obtained orthogonality in surface-harmonic yield expansions. Muon yields were aggregated on a symmetric spherical shell surrounding each meson rest frame. Low multipolarity expansion terms were found to be sensitive to forward-backward asymmetries. In contrast, high multipolarity expansion terms show sensitivity to the granular samplings of the spherical harmonics.

Other methods are being explored for measuring and parametrizing any variation from the required isotropy of muon decays (from these spin = 0 mesons). Continuous monitoring of acceptance and efficiency for STAR's Main TPC is possible using this subset of detected charged particles. This feature of isotropic decay, due to the decaying pions and kaons being spin = 0 mesons, makes the present method unique by providing a new dimension in the monitoring of STAR's Main TPC, not available in any other monitoring method.

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Wood Frog *(Rana sylvatica)* Use of Wildlife Ponds in Northcentral Arkansas

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Abstract

Forty-one wildlife ponds were monitored between 1988 and 1992 for breeding use by wood frogs *(Rana sylvatica)*. Data were collected on egg deposition and pond characteristics. Breeding activity and characteristics were similar to that reported in other portions of the range of the wood frog. We also monitored 15 newly-constructed ponds to determine chronological breeding patterns. Data collected for each site indicated a significant increase ($P \leq 0.05$) in the number of egg masses deposited in ponds as they age from 1-3 years during our study period. Increased chronological use of newly-constructed ponds may be due to localized population increase resulting from greater availability of breeding habitat.

Introduction

The range of the northern wood frog *(Rana sylvatica)* extends over much of northern North America and occurs southward into northern Arkansas where populations are somewhat discontinuous (Black, 1933; Dowling, 1956; Martof, 1970; Conant and Collins, 1991). Most published accounts in Arkansas relate to distributional records for specfic population localities (Black, 1933; Black, 1938; Dowling, 1957; Schuier et al., 1972; Robison and Douglas, 1977; Plummer and Godwin, 1979; Turnipseed, 1980, 1981; Cline and Tumlison, 1985; Trauth et al., 1987, 1995). Limited information is available on the biology and life history of wood frog populations in Arkansas. Pertinent data associated with population status, reproduction, predation, ecological associates and general habitat use are found in Trauth et al. (1989, 1995). Our study was designed to evaluate the use of both well-established and newly-constructed wildlife ponds as wood frog breeding sites.

Materials and Methods

Forty-one wildlife ponds constructed on the Sylamore Ranger District (SRD) of the Ozark/St. Francis National Forest (OSFNF) in north-central Arkansas were monitored for use by wood frogs. Data were collected over a five-year period between 1988 and 1992. All monitored ponds were constructed by the U.S. Forest Service (USFS) and/or the Arkansas Game and Fish Commission (AGFC) in order to provide year round water sources for native wildlife species.

Pond ages during the study ranged from < 1 year to 11 years. Characteristics of the ponds were addressed by Trauth et al. (1995). Wildlife ponds generally were constructed in mid-to-late summer. Immediately following construction, water capacity sufficient for breeding amphibians did not occur until fall and early winter. Ponds were monitored during the wood frog breeding season which occurred during late January through early March of each year (Trauth et al., 1995).

Data collected on or after February 15 of each year of observation were used in the analyses to reduce bias associated with variation in egg deposition periods during the annual breeding seasons. We collected data on number of communal egg mass clusters at pond sites, number of egg masses at each deposition site, water temperature at the egg deposition site (°C), maximum pond depth (cm), egg mass temperature in the center of communal clusters (°C), diameter of communal clusters (cm), and maximum water depth (cm) at the deposition site. Water depth was recorded in cm using a standard meter stick. Water temperature and egg mass temperature were recorded with a standard Celsius thermometer. Water temperature readings were recorded at a depth of 5 cm at a distance of 0.5 m from the water's edge and 10 cm from the outer edge of the egg mass cluster. Egg mass temperatures were recorded at a depth of 5 cm inside the horizontal surface of the central egg mass within a cluster.

Fifteen ponds constructed by the USFS between 1988 and 1991 were evaluated to assess the chronology of use patterns with increasing pond age. Pond ages in the analysis correspond to the number of breeding seasons following construction of the pond. The number of wood frog egg masses observed in these ponds in 1989, 1991 and 1992 provided data for evaluation of changes in breeding use. We used a single factor ANOVA to detect differences in egg mass deposition levels between years.

Results

Thirty seven (90%) of 41 ponds monitored supported breeding populations of wood frogs. Fifty eight (88%) of 66

Table 1. Differences in numbers of wood frog egg masses found in 1-4 year old ponds. NSF = no significant difference.

Pond Age (in years)	N	Average Egg Mass Size	Range
1	10	13.70	(3-31)
2	6	57.83	(20-105)
3	6	141.33	(56-226)
4	5	159.80	(99-206)

In single factor ANOVA tests, NSF between yrs. 3 vs 4; all other year combinations significant ($P < 0.05$).

pond locations had at least one communal egg mass cluster. Five (9%) of the 58 locations also contained a second but smaller secondary communal egg mass cluster. No monitored ponds contained more than two communal clusters. Mean number of egg masses for primary and secondary communal clusters for each pond was 62.14 (range 1-290) and 37.20 (range 15-63), respectively. Generally, only one communal cluster was found in each breeding pond. Maximum water depth for 44 pond locations averaged 74.34 cm (range 8-180 cm). Maximum water depth at primary sites of communal egg deposition at 14 pond locations averaged 23.46 cm (range 15-45 cm). Maximum diameter of primary communal clusters at 31 pond locations averaged 197.68 cm (range 35-570). At nine pond locations water temperature adjacent to primary clusters of egg masses and temperature for an egg mass located in the center of a cluster averaged 9.11° C (range 3.5°-14°) and 10.39° C (range 4.5°-15.4°), respectively. We found significant differences ($P < 0.05$) in the number of egg masses deposited in newly-constructed ponds, 1 - 3 years of age (Table 1). A comparison of egg deposition levels for 3 and 4 year old ponds indicated no significant differences ($P \leq 0.05$). Limited use of newly-constructed ponds was noted during the first breeding season following construction. No egg masses or frogs were observed in two newly-constructed ponds during the first wood frog breeding season following pond construction. Based on deposition of egg masses and general observations, breeding use of wildlife ponds appeared to increase for up to three years following construction.

Discussion

Data collected on wood frog breeding activity and characteristics of egg deposition for northcentral Arkansas are comparable to much of the natural history data collected in the more northern sections of the geographic range of the wood frog (Seale, 1982; Waldman and Ryan, 1983) and also on the southern periphery of the range (Davis and Folkerts, 1986; Camp et al., 1990). Average and maximum water depth at oviposition sites in Arkansas ponds was slightly greater than depths reported in Alabama (Davis and Folkerts, 1986). This may be due to the fact that ponds in Arkansas were slightly larger and classified as permanent whereas ponds in Alabama were classified as shallow and temporary.

Number of egg masses at communal oviposition sites varied considerably ranging up to a maximum of 290. During a three-year study in Colorado and Wyoming, Corn et al. (1989) reported a maximum of 38 egg masses at individual pond sites. Davis and Folkerts (1986) reported a maximum of 147 egg masses at a communal oviposition site in Alabama. In contrast, Seale (1982) reported a maximum of 963 at a site in Pennsylvania. Different selective pressures in different environments may confer differential selective advantages of particular reproductive characteristics (Berven 1982a,b). Lower number of masses in oviposition sites in the Rocky Mountains may result from the presence of very small disjunct relict populations (Hammerson 1982b). Lower number of masses in southern latitudes may relate to warmer climatic conditions, earlier breeding, and a reduced need for accelerated development which favors a larger cluster of masses.

Our data indicate that wood frogs increase breeding use of newly-constructed ponds over time based on number of deposited egg masses. Corn et al (1989) could not identify trends in wood frog populations in the Rocky Mountains based on numbers of deposited egg masses over a three-year period. This may have been due to the fact that small established relict populations were studied in areas where available breeding habitat did not change appreciably which was unlike conditions in our study in Arkansas. Although this

variation in breeding use of ponds in Arkansas could be attributed to annual variations in egg deposition due to variability in winter adult survivorship (Seale, 1982), we believe this is not likely in southern latitudes where winters are considered mild compared to winters in the more northern portions of the distribution of the wood frog. In Arkansas it is conceivable that increased use of breeding ponds may be due to localized population increase as newly-constructed ponds create additional breeding habitat.

Long-term assessment will be necessary to identify wood frog population trends. It is likely that current populations, at least on USFS lands, will remain somewhat stable as overall habitat management likely will not change drastically over time. Generally populations are not expected to increase significantly on USFS lands because the rate of establishing new wildlife ponds which serve as additional breeding habitat is expected to decline. This primarily is due to the fact that wildlife ponds are established for white-tailed deer *(Odocoileus virginianus)* and wild turkey *(Meleagris gallopavo)*, and the present number and distribution of ponds appear to be nearing an adequate level for supporting acceptable populations of these species. The fate of wood frog populations is more uncertain on private lands as more and more forest land within the range of the wood frog in northern Arkansas is being cleared for cattle pastures and hay meadows.

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In-Stream Monitoring of Sediments and Water in the Lower Ouachita River for Site Impact to Aquatic Biota

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Abstract

Reported reduced sportfish densities in the main channel of the Ouachita River prompted an investigation, beginning in 1990, into potential causes of ongoing impairment to aquatic biota. In-stream monitoring that incorporated toxicity testing of sediments and water was conducted to discern potential sources of contaminants that might be related to the suboptimal fishery populations. Organisms selected to evaluate chronic impairment included larval fish, clams, midges and water fleas. The fathead minnow (*Pimephales promelas*) and cladoceran (*Ceriodaphnia dubia*) were used to estimate patterns of toxicity associated with water from seven designated reaches and selected tributaries of the Ouachita River. Larval survival and growth tests were conducted using the fathead minnow, while survival and reproduction were assessed for the cladoceran. An enzyme assay using the Asian clam (*Corbicula fluminea*), and growth and survival tests with *Chironomus tentans* were used to evaluate ambient sediment toxicity within these same reaches and tributaries. Ambient toxicity was rarely observed in the mainstem of the River and, moreover, represented intermittent events. However, impaired growth in larval fish, poor reproduction in cladocera, and reduced enzyme activity in clams were evident for several tributaries. Results of 10-day whole sediment tests showed significant growth reductions in *C. tentans* exposed to sediments collected from West and East Two bayous, Smackover and Coffee creeks. These results suggest there is intermittent impairment in tributaries of the Ouachita River due to ambient water and sediment conditions that are aside from current concerns for mercury contamination.

Introduction

Although chemical monitoring of specific contaminants may validate the use of water quality criteria, concern over bioavailability and effect requires an integrated approach to insure human health and maintain biological communities. Information gathered from a series of stream fishery surveys conducted by Arkansas Game and Fish Commission fisheries biologists from 1987 to 1990 supported the contention that traditional fisheries management efforts would not be sufficient to improve the river's fisheries with such a diverse array of known anthropogenic impacts (Wise et al., 1993). In 1990, concern over reported reduced sportfish densities in the main channel of the Ouachita River prompted the formation of the Lower Ouachita River Work Group (LORWG) to evaluate chemical and biological monitoring of the basin. The lower Ouachita River is defined as that reach which extends from downstream of Remmel Dam, which impounds Lake Catherine, to the Arkansas Louisiana State Line, downstream of the Felsenthal Lock and Dam. This lower section of the Ouachita River has historically been impacted by the release of water from upstream reservoirs, which has had an effect on flow patterns, temperature and water chemistry (Nix et al., 1996). Additionally, several agricultural, municipal and industrial sources are known to contribute to both point and nonpoint discharges. Downstream from Camden, brine and petroleum products have had a significant impact in the past. Before the river exits the state, Felsenthal Lock and Dam furnishes a large green tree reservoir managed for fish and wildlife.

During a 1991 review of available river data from various state and federal agencies, LORWG determined that additional studies were needed to evaluate whether contamination sources or effects were the cause for the reduced fishery resources of the river. These additional assessments included evaluations of water and sediment quality (Nix et al., 1996), fish community structure (Price and Rodgers, 1996), fish bioaccumulation, mussel community analysis (Posey et al., 1996), flow regimes and river flood history (Lee, pers. comm.), and ambient water and sediment toxicity presented in this study.

This study presents the summary of measured in-stream and laboratory impairment of water and sediment-dwelling organisms exposed to ambient conditions in the lower Ouachita River. Beginning in August 1992, ambient toxicity screening of seven tributaries and the main stem of the Ouachita River was initiated with standard test organisms. Toxicity tests were performed on ambient water from the

Table 1. Location limits for each identified segment of the Ouachita River.

Segment Number	Location (km downstream of Remmel Dam)	
1	Remmel Dam to Rockport	(3.7)
2	Rockport to confluence with Caddo River	(16.1)
3	Confluence with Caddo River to confluence with Little Missouri River	(107.8)
4	Confluence with Little Missouri River to Camden, AR	(115.9)
5	Camden, AR to confluence with Smackover Creek	(215.7)
6	Confluence with Smackover Creek to upper end of Felsenthal Pool	(267.2)
7	Felsenthal Pool	(326.7)
8	Felsenthal Dam to Louisiana state boundary	(337.9)

main stem of the Ouachita River on seven occasions between July 1992 and July 1993. Tributary samples were collected and tested from one to six times through 1994. Sediment characterization, sediment toxicity testing using an invertebrate species, and 30-day in situ monitoring using Asian clams were utilized to aid in the evaluation of sediment contaminant data.

Materials and Methods

Description of Sites.--The Ouachita River headwaters arise in the Ouachita Mountains Ecoregion near Mena, Arkansas and drain a portion of the Ouachita Mountains composed mostly of sandstone and shale. The river flows almost due east through three impoundments (Lakes Ouachita, Hamilton, and Catherine) before the gradient changes significantly as it enters the Gulf Coastal Plain near Malvern and changes again downstream of Camden (ADPC&E, 1987). Here, the river is more characteristic of a lowland stream and is affected by land use and drainage of the lower Ouachita River watershed. The river was divided into eight segments for the LORWG investigation (Nix et al., 1996) on the basis of tributary confluences, hydrologic structures or other stream features (Table 1). Specific river sites or stations in toxicity evaluations were selected to delineate areas of suspected impact either from tributaries or river sections known to have reduced fish densities or displaying ambient toxicity revealed in a 1992 screening study. A total of 23 stations contained within eight segments was sampled from July 1992 through December 1994 (Table 2). It should be noted that Reach #7 covers the pool formed by Felsenthal Lock and Dam. This section of the river is affected by processes different from those governing a strictly riverine environment and was therefore not sampled and evaluated for ambient toxicity screening.

Ambient Water Toxicity Testing.--Beginning in 1992, samples were collected from major tributaries of the Ouachita River. Tributaries were screened for toxicity and impairment on a convenience basis prior to 1994, however, exclusive screening of major tributaries was conducted during 1994. Water samples were collected at midstream of each location, and samples from tributaries were usually collected from the bank or a bridge. Efforts were made to collect samples away from pools and primary tributaries. An eight-liter sample provided ample water for use in toxicity tests and routine chemical analysis. Water samples were placed in polyethylene bottles, iced, and returned to Ouachita Baptist University (OBU) laboratories for analysis. If toxicity tests were initiated on the day the samples were collected, then samples were not cooled upon collection. Temperature, dissolved oxygen, specific conductance, and pH were measured in situ using a Hydrolab Surveyor II® system calibrated according to manufacturer's specifications

Table 2. Description of sampling locations for sediment and water in the lower Ouachita River used for toxicity assessments conducted from July 22, 1992 through December 1, 1994.

Station	Site Description	Station	Site Description
1A	0.4 km downstream of Remmel Dam	6A	West Two Bayou
1B	1.2 km downstream of confluence with Cove Creek	E2b	100 m upstream of West Two Bayou
2A	1.5 km upstream of confluence with Chatman Creek	E2B	East Two Bayou
2B	4.0 km downstream of confluence with Chatman Creek	6A	Upstream of Champagnolle Creek, 1.0 km downstream of confluence with Smackover Creek
3A	1.0 km upstream of confluence with Reynold's Ditch	6B	0.5 km downstream of confluence with Champagnolle Creek
4A	Reynold's Ditch	6C	0.7 km downstream of Cation Lake
5A	1.0 km upstream of confluence with Little Missouri River	6D	0.5 km upstream of confluence with Moro Bayou
5B	1.0 km downstream of confluence with Little Missouri River	6E	1.0 km downstream of confluence with Moro Bayou
5C	0.5 km upstream of Highway 7 bridge at Camden	7A	Inflow to Felsenthal Pool
E2A	3.0 km downstream of Highway bridge at Camden	8A	1.0 km upstream of confluence with Coffee Creek
E2b	1.5 km upstream of confluence with Smackover Creek	C	Mouth of Coffee Creek
		8B	0.5 km downstream of confluence with Coffee Creek

each day prior to use. Alkalinity, hardness, and pH were determined in the laboratory according to methods described by the American Public Health Association (1992) or the U.S. Environmental Protection Agency (U.S. EPA, 1970).

Chronic Toxicity Screening.--Chronic toxicity tests were conducted on water samples collected from each of the seven designated reaches and selected tributaries of the Ouachita River. These ambient toxicity tests were conducted utilizing the microcrustacean, *Ceriodaphnia dubia*, and the fathead minnow, *Pimephales promelas*. Methods follow those outlined by U.S. EPA (1989) with the following modifications cited by Knight and Waller (1987):

1) Daily sample water renewals for both *C. dubia* and fathead minnow tests were made from a single sample stored at 4°C between renewals;
2) *C. dubia* were fed a combination of green algae, *Selenastrum capriconutum* and an extract of cereal leaves, Cerophyl;
3) Statistical design for *C. dubia* tests utilized a randomized block design, while the design for fathead minnow tests utilized a completely random design.

Test Endpoints.--The endpoints of *C. dubia* tests were acute survival and chronic productivity. Productivity is defined as the number of young produced per female over the course of seven days. *C. dubia* will produce their third brood within the seven-day test duration. The endpoints for fathead minnow tests consisted of survival and growth, with growth measured as mean dry weight of test organisms after seven-day exposures. Due to the nature of sampling on the

Ouachita River (by reach), ambient toxicity tests were used to identify areas of the river that were consistently impacted. However, identifying the source for measured in-stream impairment was limited since ambient testing differs from effluent evaluations. Ambient tests can provide information on toxicity patterns associated with a water body that enables investigators to pose hypotheses about the sources of toxicity.

Statistical Methods.--All chronic data using *C. dubia* and *P. promelas* were analyzed using TOXSTAT software (Gulley et al., 1991). Data were evaluated for normality and homogeneity of variances prior to subjection to analysis of variance (ANOVA). If the data were found to be normally distributed and the variances homogeneous, Tukey's Multiple Comparison Procedure was utilized to determine statistically significant differences. If the data did not follow a normal distribution, or if the variances were heterogeneous, then the nonparametric Kruskal-Wallis procedure was used. Performance controls (OBU laboratory water, reconstituted moderately hard) were analyzed with the ambient water toxicity data.

In-stream Monitoring of Clams.--Adult Asian clams, Corbicula fluminea. used for monitoring were collected from the Middle Fork of the Saline River near the town of Benton, Saline County, Arkansas in July 1993. Prior knowledge of the condition of this collection site was provided by John Harris (pers. comm.). Clams were sorted according to shell length and selected to range in size from 14 to 16 mm, and allowed to acclimate in the Ouachita River downstream of Remmel Dam. Clams were kept in chilled, aerated river water between stations from the time of collection until arrival at monitoring placements. Upon arrival at each monitoring location, thirty clams were sorted into each of three plastic crates measuring 180 mm x 180 mm x 180 mm. Crates were lined with number 20 fiberglass screen mesh (850 micrometer opening) and filled with cobble to provide substrate for the clams and a settling surface for collected fine silt. Crates were then secured into a group of three and lowered at each sampling location to a depth of 2-3 m and secured to a tethered line extending from a marked shore object (either tagged trees or major snags). At the time of placement, sediment samples were collected from each site location using a petite ponar dredge (150 mm x 150 opening) preserved in plastic bags, chilled and transferred to the laboratory for characterization.

After one month of exposure, clams were retrieved from crates, dissected aboard the boat, transferred to cryovials, and frozen in liquid nitrogen until enzyme analysis could be performed at Arkansas State University's (ASU) Ecotoxicology Research Facility. Sediments were again collected by petite ponar from each location in September 1993 and preserved. Sediment accumulated in each crate was transferred to bags immediately after retrieval, chilled, and transported to the laboratory for characterization and use in *Chironomus* testing. Overlying water was retained in all bags until laboratory use, insuring that sediments remained hydrated until analysis. Clams collected from baskets were used for evaluation of cellulolytic activity and tissue analysis.

Cellulolytic Enzyme Assay.--Six clams from each site were randomly chosen and dissected for cellulolytic enzyme analysis according to methods used by Farris et al., 1989. Since degradation of substrate cellulose takes place through the combined action of endocellulase and exocellulase, the product of two specific assays was used to determine the activity level of the enzyme group of the monitored organism. Endocellulase, with a synthetic cellulose medium [1% carboxymethylcellulose, (CMC) solution] as a substrate, was assayed for viscosity changes based upon the rate and amount of breakdown of 1 mg of reduced sugar by the available cellulases within the organism at the time of dissection. Exocellulase uses a combination of CMC as the substrate and dinitrosalicylic acid (DNS) as a color indicator to bind with any accessible glucose liberated during the degradation of available cellulose (Farris et al., 1989). The product of the two measurements was used to determine accessible enzyme availability extracted from the clams.

Enzyme extracts from individual clams were prepared from whole-body homogenates. Samples were homogenized in phosphate buffer at pH 6.1 at a wet mass to buffer ratio of 0.2 g/ml. Samples were centrifuged for 15 minutes at 15,000 rpm, supernatants decanted for endo/exocellulase analysis, and the pellets recovered for dry mass measurements.

Statistical Analysis.--One-way analysis of variance (ANOVA) was used to evaluate the effects of site water on *C. fluminea* cellulolytic activity (Statistical Analysis Systems, 1985). Significance was inferred $\alpha = 0.05$, and Duncan's multiple range test was used to determine means that were significantly different from control activities.

Sediment Toxicity Tests.--*Chironomus tentans* were used in ten-day, solidphase tests to determine relative toxicity among collection sites (U.S. EPA, 1994). Sediment grab and trap samples were collected from 11 sites in the Ouachita River basin during August and September 1993. Samples were transferred to 500-ml plastic bags and cold packed in coolers. Coolers were then shipped overnight to the Arkansas State University (ASU) Ecotoxicology Research Facility. Upon arrival, samples were checked for chain of custody records, and then transferred to a refrigerator for storage. Prior to all toxicity tests, sediments were homogenized by stirring with a spoon.

Approximately 400 ml of the homogenized sample was then sieved through a #40 (425 µm), #270 (53 µm), and a collecting pan sieve series using one liter of moderately hard synthetic water used as the overlying water. The fraction collected in the #270 sieve was used as the test sediment. The water, including the silt fraction in the collecting pan, was

Table 3. Measured impairment and toxicity in *Ceriodaphnia dubia* and *Pimepales promelas* exposed to ambient water from sites throughout the lower Ouachita River, July 22, 1992 through December 1, 1994. The number of toxicity tests conducted per site are shown with dates for the collections that elicited chronic impairment.

Site	*Cerodaphnia dubia*	*Pimephales promelas*	Site	*Cerodaphnia dubia*	*Pimephales promelas*
1A	9	9 (7-22-94)‡	6E	8	7
1B	9 (12-1-94)‡	9	7A		
2A	7		8A	10(1-14-93)‡	10(1-14-93)‡
2B	7		C	2†‡	3
3A	7	7	8B	10(1-14-93)†‡	10(7-22-94)‡
3B	7	7	E2A		
3C	7		E2b		
4A	7		E2B	2(10-23-92)†‡	
5A	10(1-14-93)†‡	10(9-16-93)‡	Champagnolle Creek	1(8-21-92)†‡	
5B	10	10(9-16-93)‡	Smackover Creek	1	
5C	12	12(8-5-94)‡	Cove 1	3(4-16-94)‡	2(12-1-94)‡
6A	15(1-14-93)†	13(8-5-94)†	Cove 2	3(4-16-94)‡	2(12-1-94)‡
6B	11	10	Coffee Creek 1	2(7-22-94)‡	3
6C	7	7	Coffee Creek 2	2(12-1-94)‡	3
6D	8	7	Coffee Creek 3	2(7-22-94 / 12-1-94)‡	3

†Statistically significant difference in survival
‡Statistically significant difference in productivity (growth or reproduction)

used as overlying water. The fine particles suspended in water were allowed to settle for 24 hours. Approximately 30 ml of sediment from the #270 sieve was placed in a 250ml beaker. The dilution water from the collecting pan was placed in a beaker, resuspended by stirring, and 150 ml was poured gently into the beaker. Test chambers were covered and placed in a temperature-controlled room or incubator at 23±2 °C, and sediment was allowed to settle for 24 hours. All test chambers were continuously aerated and oxygen levels maintained above 5 mg/L. After settling for 24 hours, ten 3rd-instar larvae cultured in house at ASU were added from a newly-hatched culture unit from each replicated test vessel. All larvae were released beneath the water surface using a widebore, fired pipette to avoid entrapment of air bubbles which may cause floatation. Individuals found floating were removed and replaced with larvae from the same culture unit. Each beaker received a 0.5 ml suspension of Tetramin® flake food, and renewed overlying water, daily. Moderately hard synthetic water was used as overlying test water and renewed by siphoning approximately 2/3 of the volume from each chamber.

The test was terminated after ten days of exposure by pouring the contents of each beaker through a #40 (425 µm) sieve. The contents in the sieve were rinsed into a sorting tray, and larvae were collected and preserved in ethanol. The number of individuals recovered in each beaker was recorded. The larvae were placed in labeled, tared aluminum boats and placed in a drying oven for at least two hours at 100°C. The boats were transferred to a desiccator for at least 1 hour and weighed. Mean dry weights of each replicate were taken to compare net weight gain among exposed individuals for each of the 26 sites tested. Significant differences in growth and survival among sites were determined using Dunnett's analysis. Analysis of variance procedure was used to compare *C. tentans* survival and weight gain among all the site sediments (U.S. EPA, 1989).

Sediment Characterization.--Sediment characteristics routinely studied in association with toxicity testing were included for analysis based on their anticipated effects on contaminant sorption to bottom sediments. Particle size composition, cation exchange capacity (CEC), percent total solids and pH were determined as in Moore et al. (1996) on sediments from 11 study sites.

Results and Discussion

Ambient Water Toxicity Screening.--The main stem of the Ouachita River was sampled for toxicity screening seven times between July 1992 and July 1993. Samples were collected on twelve occasions from seven tributaries between August 1992 and December 1994. Toxicity evaluations on ambient water using *C. dubia* and *P. promelas* for all sites are summarized in Table 3. Testing in August 1992 established that toxic responses were measurable in *C. dubia* exposed to water collected from the mouth of Champagnolle Creek.

Table 4. Cellulolytic enzyme activity measured from *Corbicula fluminea* in 30-day in situ exposures, at 10 river locations in the lower Ouachita River.

River Sites	Product	Index	River Sites	Product	Index
Reynolds Ditch (3B)	1171.9 (±205.6)	18 (±3)	Champanolle (6B)	1130.8 (±245.5)	17 (±4)
Little MO (4A)	374.2 (±138.4)	6 (±2)	Felsenthal (7A)	50167.7 (±681.7)	76 (±10)
E2A	1356.1 (±183.5)	20 (±3)	8A	6638.7 (±1198.7)	100 (±18)
E2b	4660.3 (±1494)	70 (±23)	Coffee Creek (C)	1234.1 (±529.0)	49 (±8)
E2B	2365.2 (±475.9)	36 (±7)	8B	3729.7 (±2127.3)	56 (±32)
Smackover (6A)	1417.7 (±165.9)	21 (±3)			

The mean productivity of 4.5 young per female, was statistically different from productivity measured in water exposures from Station 5C, Smackover Creek and Station 6A. Large variance measures were associated with mean production estimates for stations and often resulted in failure of the homogeneity test on additional test dates. Description of test means for reproduction and survival can be found in greater detail in Knight et al. (1995).

Impairment of both reproduction and growth, as well as toxicity, was rarely observed in either *C. dubia* and *P. promelas* when exposed to water from the mainstem of the Ouachita River. However, toxicity to *C. dubia* was measured in at least one section of Champagnolle Creek four of the five times this site was tested. Repeated test impairment and mortality was also measured in *C. dubia* when exposed to water from East Two Bayou (four of five times tested) and from West Two Bayou (three of five times tested). Toxicity in *P. promelas* was observed in the testing of water from East Two Bayou during September 1993. This corresponded with significant impairment of reproduction measured in C. dubia when exposed to the same water. Impairment in reproduction and growth for *C. dubia* and *P. promelas*, respectively, was measured in water collected during July 1994 at Cove Creek. This was the greatest significant reduction in measured parameters obtained during the toxicity assessment.

In-stream Clam Monitoring.--The use of *Corbicula* as a suitable surrogate for native freshwater bivalves has been successfully validated in several monitoring studies (Farris et al., 1988; Farris et al., 1996; Milam and Farris, 1998). Clams have been shown to establish significant biomarker responses to in-stream exposures of various metal discharges and to recover to background physiological conditions following removal of the exposure. Cellulolytic activity measured in *Corbicula* from the Ouachita River varied from 6,638 x 10^5 to 1,130 x 10^5 units/g dry weight for stations sampled. The highest enzyme activity was found in clams collected approximately 6.5 km downstream of Felsenthal Dam (Station 8A) and at the inflow to Felsenthal Reservoir (Station 7A) (Table 4). The remaining clams from all other in-river stations located downstream of tributaries showed reduced enzyme activity. Most notable activity reductions were found in clams held at stations within influence of East and West Two bayous (reductions to 36 and 20% of upstream activities, respectively) and clams downstream of both Smackover (21% of upstream) and Champagnolle (17% of upstream) creeks. Clams did not display significant mortality in any of the replicate baskets for all sites during the month-long exposures. The observed low digestive activity in clams from the Little Missouri River was attributed to low production in the river as gut contents were noted to contain less mass and color than in clams from the Ouachita River. This observed difference in enzyme activity between clams from tributaries and mainstem rivers has been measured and validated in comparisons of the Guest and Clinch rivers in Virginia (Farris et al., 1996). However, the reduction to 18% of upstream activities in clams from Reynold's Ditch was not attributed to absence of sufficient organics or suspended matter for feeding. Indeed, the observed amount of gut contents would suggest that the clams were actively processing food but failed to utilize useable foodstuffs due to measured enzyme reduction. Clam enzyme assays measured reduced glucose equivalents from areas that have been suggested as possibly impacted with regards to native mussel densities (Harris, 1991). The same sites noted by Harris as having poor mussel communities from the East Two Bayou confluence to downstream of Champagnolle Creek are comparable to sites having reduced cellulolytic

Table 5. Results of 10-day sediment toxicity tests using C. tentans exposed to sediments collected from the lower Ouachita River using a ponar grab sampler and in-river sediment traps. Values represent mean survival and growth following acute tests.

	Survival (%)		Growth (mg)			Survival (%)		Growth (mg)	
	Ponar	Trap	Ponar	Trap		Ponar	Trap	Ponar	Trap
Reynolds Ditch (3B)	47	–	0.07	—	Smackover (6A)	63	–	0.02	—
Little MO (7A)	93	83	0.13	0.21	Champagnolle (6B)	100	100	0.14	0.20
E2A	90	93	0.21	0.05*	Felsenthal (7A)	83	93	0.11	0.63
E2b	60	97	0.06	0.04*	Coffee Creek (C)	83	87	0.09	0.27
E2B	46	90	0.06	0.03*	8B	87	100	0.18	0.13

*Values were statistically significant between tested groups.

activity from these studies. Overall, the mussel community of the lower Ouachita River is similar in species composition, distribution, and density when compared to other rivers of the state (Posey et al., 1996). However, Posey (1997) stated that nearly all collected from the Ouachita River were "dwarfed" when compared to those of other rivers. This phenomenon of reduced growth is unexplained to date and doesn't seem limited to site specific locations along the river.

Cellulolytic activity of clams in the Ouachita River appeared altered in a predictable fashion in relation to suspected impacted areas of the river. However, variability in enzyme activity from the upstream clams not experiencing effluent or chemical treatment was large at times. The sensitivity of detecting statistically significant changes across stations was reduced by this variability. The importance of the cellulolytic enzyme complex for providing usable foodstuffs for clams, mussels, and snails appears intuitively correct in that previous studies (Farris et al., 1988; 1989) suggested declines in cellulase activity cascaded into growth reductions and preceded mortality and changes in glycogen content (Haag et al., 1993). Unionids and clams feed by siphoning small particles from the water column or water-sediment interface. Feeding by these bivalves may be impaired by loss of suspended particles, behavioral avoidance of contaminants, or actual inhibition of digestive enzymes by associated bioaccumulation.

Chironomus tentans *Growth on Sediments.*–Results of 10-day tests with *C. tentans* on sampled sediments of the Ouachita River showed statistically significant differences in reduced growth from stations around West and East Two Bayous (E2A, E2B,E2b), Smackover (6A), and Coffee (6B) creeks (Table 5). Tests utilizing ponarcollected sediment from Station 6A downstream of Smackover Creek resulted in the lowest measured *C. tentans* growth in six series of tests from all stations (individual dry weight = 0.02 mg). Growth of *C. tentans* on control sediments must produce 0.06 mg for individual dry weight. Two separate tests upon the same sediment (6A) measured growth per individual below 0.03 mg. Mortality in these tests was not a significant factor in reducing growth estimates per individual by reducing the sample size comparisons among stations. Rather, *C. tentans* only had reduced survival to 50% upon sediments from Reynolds Ditch and downstream of Station E2B. Collection method was not a factor for sediment from Station E2B as tests with both trapped and grabbed sediments resulted in growth impairment. However, measured impairment in recently deposited sediments was evident from other stations comparing ponar and trap samples.

Any correlation between growth impairment and sediment characterization was not apparent from these tests. However, there is a strong indication that the observed impairment from sediment tests is in agreement with areas where the clam enzyme reductions were most apparent. Clam responses during in-stream monitoring efforts, growth tests from collected sediments, and Harris' (1991) mussel surveys form a collective indication that reductions associated with siphoning, sessile animals or with macroinvertebrates that ingest affected sediments are able to delineate impact zones within the Ouachita River. Macroinvertebrate surveys conducted by Price and Rodgers (1996) also reported impacted communities downstream of West Two Bayou near Camden to just upstream of Smackover Creek and downstream of Felsenthal Dam. While habitat variations were reported to account for linear declines in the upper Ouachita comparisons, they could not account for all of the differences noted in sites downstream of Camden and

Felsenthal Dam. Those results also support the observed differences in fish communities downstream of Reach #4 reported by Wise et al. (1993). Causes for measured spatial fluctuations in the fish community have also indicated point source impacts related to areas affected by West Two Bayou and Smackover Creek.

Sediment Characterization.--Sediment characteristics varied among sites, but were similar among replicated samples (Tables 6 and 7). Reynolds Ditch had the highest percent of sand and clay particles with calculated values of 75.3 and 6.5%, respectively. Trap samples from site E2B had the greatest percent silt, 96.3%. Percent total solids varied from 34.7- 78.7% among all sites collected in September 1993. Measured values for pH were similar among all sites, ranging from 5.24 at E2b in August 1993 to 7.48 downstream of Little Missouri River (LM) in September of the same year. Cation exchange capacity was less than 3.0 for sediments collected from all sites, with the exception of trapped sediments collected from Site 7A (4.3).

Sediment characterization indicated that sites were variable in relation to those parameters measured in this study. However, one important parameter that should be analyzed in future work, is total organic carbon (TOC). Laboratory and field data support the contention that TOC concentrations in sediment control the availability of organic chemicals to interact with organisms (Giesy et al., 1990). This analysis, combined with analytical evaluation of available water soluble fractions of contaminants, would allow better delineation of impacted areas having reduced growth of *Chironomus* and clam enzyme activity.

Measured impairment responses were coincident in sampled sediment and water from East Two Bayou, Smackover and Coffee creeks, and to a lesser degree in Champagnolle Creek and downstream of Reynolds Ditch (Table 8). The potential cause of the observed impairments may be explained in part by water and sediment conditions measured during September 1992 through September 1993 (Nix et al., 1996). Measured water quality parameters that exceeded the Arkansas Water Quality Standards (WQS) for pH, turbidity, and certain trace metals were sufficient to impact biota as measured and represented by both acute and chronic aquatic life criteria. While most measured concentrations of pesticides were very low, dieldrin concentrations exceeded the proposed federal criteria at a number of sites. If not for sediment TOC concentrations exceeding 5% in the lower Ouachita River, dieldrin would be expected to exert a greater influence at all sites. Significant increases in measured water quality parameters such as specific conductance, alkalinity, and turbidity were often correlated with high concentrations of sulfate, chloride, and trace metals for the three impacted tributary sites and East Two Bayou. Elevated zinc, copper, and arsenic concentrations in Coffee Creek, as high as 10 times the acute Arkansas WQS were measured in January 1994. High concentrations of cadmium, copper, nickel, and zinc (as high as 35 times the zinc WQS, specifically) were again evident in July 1994. Elevated concentrations of nickel, chromium, vanadium, and zinc were measured in Champagnolle Creek in October

Table 6. Characterization of Ouachita River sediments collected by ponar dredge and silt trap on September 14, 1993.

Site	pH	Temp (°C)	Sand (%)	Silt (%)	Clay (%)	CEC	Total Solids (%)
Reynolds Ditch	6.45	10.0	75.3	18.2	6.5	3.0	41.4
8B-trap	6.07	10.6	16.0	82.4	1.6	1.7	78.0
8B-ponar	6.06	11.9	59.5	10.5	0.0	0.7	72.2
7A-trap	5.54	11.8	7.4	92.6	0.0	4.3	34.7
7A-ponar	6.83	12.8	21.5	78.8	0.0	2.4	50.2
6B-trap	5.95	15.1	12.4	87.6	0.0	2.7	52.8
6B-ponar	6.35	15.9	50.5	49.5	0.0	1.3	69.9
6A-trap	6.29	13.4	25.2	73.3	1.5	1.8	55.5
6A-ponar	6.58	8.1	44.1	55.9	0.0	1.4	76.6
Coffee Creek-trap	6.97	9.4	13.4	86.7	0.0	2.8	52.8
Coffee Creek-ponar	6.64	9.4	60.4	39.6	0.0	1.1	72.0
8A-trap	7.30	12.5	28.9	71.1	0.0	1.0	50.0
8A-ponar	6.54	7.6	60.2	38.2	1.6	0.9	73.6
Little MO-ponar	7.48	9.8	55.5	39.1	5.4	1.2	79.6
E2B-trap	6.70	10.8	7.9	96.3	0.0	2.0	45.2
E2B-ponar	5.88	11.5	54.2	45.8	0.0	1.8	78.7
E2A-trap	6.81	10.5	6.4	93.6	0.0	1.6	44.5
E2A-ponar	6.01	10.5	44.0	61.6	0.0	–	64.9

Table 7. Characterization of Ouachita River sediments collected by ponar dredge on August 5, 1993.

Site	pH	Temp (°C)	Sand (%)	Silt (%)	Clay (%)	CEC	Total Solids (%)
Reynolds Ditch	–	–	–	–	–	–	82.7
E2A	6.49	19.1	68.2	31.8	0.0	0.5	71.6
E2b	5.24	12.5	42.8	57.2	0.0	0.8	67.9
E2B	6.40	13.1	43.0	57.0	0.0	1.0	64.7
6A	6.12	11.8	48.5	51.5	0.0	0.4	72.4
6B	6.12	12.6	58.9	41.1	0.0	0.7	77.0

Table 8. Coincident impairment measured from nine sites in the lower Ouachita River, downstream of Camden, AR on October 5, 1993. Checks represent measured parameters that were significantly reduced ($\alpha = 0.05$).

	C. fluminea Enzyme Activity	*C. tentans* Survival & Growth	*C. dubia* Survival & Reproduction	*P. promelas* Survival & Growth
River Sites				
Reynolds Ditch (3B)	✓	✓		
E2A	✓	✓		
E2b		✓		
E2B		✓	✓	
6A	✓	✓	✓	✓
6B	✓		✓	✓
8A			✓	✓
Coffee Creek (C)		✓	✓	✓
8B			✓	✓

1994. Elevated water quality parameters on separate dates and at the sites delineated by these toxicity and impairment assessments suggest that the study did serve to screen stations for suspected impact on the lower Ouachita River.

Monitoring efforts designed to address the link between contaminants and adverse impacts on aquatic communities in the ambient environment have been recently previewed extensively in such large watersheds as the Chesapeake Bay (Hall and Alden, 1997). As in this study of the Ouachita River, ambient toxicity tests have been utilized on a much broader scale than traditional effluent toxicity tests. These ambient toxicity tests are now being used in a tiered approach to identify areas where future assessment efforts are warranted. The two-year database showed that responses from both water column and sediment tests, measured at specific stations, were generally similar. The ambient toxicity data collected during this study demonstrate the need for integrated, multispecies water and sediment evaluations to strengthen impact assessments.

What began as routine sampling of fish populations in the lower Ouachita River has now not only indicated suboptimal fish population levels, but has drawn attention to the presence of toxic effects on other aquatic communities in contaminated areas. This assessment of biologically significant environmental contamination eventually widened to include an advisory against the consumption of fish in Louisiana sections of the Ouachita River because of mercury contamination. Fish in the portion of the Ouachita River downstream of Smackover Creek to the Louisiana border were found to contain mercury concentrations that exceeded the U.S. Federal Food and Drug Administration's (FDA) recommended advisory limits of 1.0 ppm. A health advisory on the consumption of predatory fish was subsequently issued by the Arkansas Department of Health in 1992.

Now that ambient toxicity screening of water and sediments has been field validated with a suite of sensitive lethal and sublethal bioassays for resident aquatic organisms, risk ranking is needed to substantiate cause and effect relationships that are aside from current concerns for mer-

cury contamination. It is clear from this study that some sites are contaminated, and others demonstrate localized ambient toxicity. Application of risk ranking methods, such as those used by Hartwell (1997), can be used to assess (1) whether localized toxic contaminant effects are influencing populations in the lower Ouachita River as a whole, (2) if low-level but wide spread contamination is a greater problem, or (3) if a combination of the two is at work. Such approaches assume that biologically significant environmental contamination is not necessarily predictable based solely on chemical analysis. This is confirmed with the current bioaccumulative properties of mercury in areas of the river where water and sediment mercury values are typically below detection (Nix et al., 1996). Confirmed high levels of trace metals and one pesticide in at least three areas of the lower Ouachita River suggest that future adverse effects on aquatic communities may be linked to bioavailable contaminants shown to exert effects in bioassays.

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Analysis of a Mixture of Several Dihalonicotinic Acids by Gas Chromatography and Gas Chromatography-Mass Spectrometry

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Abstract

Six 2,5- and 5,6- dihalonicotinic acids in a mixture were converted to their corresponding methyl esters and then analyzed by gas chromatography and gas chromatography-mass spectrometry. Four methods of conversion were compared for their GC sensitivity, efficiency and analysis time. In Method #1, using HCl and methanol as the reagents, the displacement of the halogens by chlorine (from HCl) at 2- and 6-positions was a common occurrence, rendering the method inefficient. In Method #2 (BF_3/methanol), the displacement of halogens by methoxide was evident. Method #3 (dicyclohexylcarbodiimide/methanol) produced a mixture of derivatives with a poor yield. Method #4 (diazomethane) gave a quantitative yield of the corresponding methyl esters without any side reactions and was suitable for analytical method development. The latest method provided short analysis time with all six methyl dihalonicotinates eluting within nineteen minutes. The resolution of the ester peaks was excellent and the detection limit was about 1 ng/μL for the dihalonicotinic acids.

Introduction

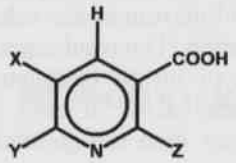
Nicotinic acid, also known as niacin, is an essential vitamin that contributes to the metabolism of carbohydrates and fats, the production of certain hormones, the functioning of the nervous and digestive systems, and the maintenance of healthy skin (Clayman, 1989). It is interesting, therefore, to study some of its derivatives to determine any beneficial properties. As many as twenty-six of the possible thirty-two 2,5- and 5,6-dihalonicotinic acids have been synthesized (Setliff, 1970; Setliff and Rankin, 1972; Setliff and Price, 1973; Setliff and Lane, 1976; Setliff and Greene, 1978; Setliff and Huie, 1981). The primary purpose of the synthesis of these compounds was to investigate their potential anti-arthritic, anti-viral, anti-psoraisis, or anti-bacterial properties. Other researchers have also studied these compounds as potential hypolipidemic agents (Gacek et al., 1972) Consequently, it has become quite important to develop sensitive analytical methods to determine the presence of these compounds in trace quantities, so that their potential application as pharmaceutical or agricultural agents can be evaluated in terms of their potency, toxicity, and metabolic transformation in living systems.

A survey of the literature reveals no analytical method available for the separation of the dihalonicotinic acids in a mixture. However, nicotinic acid and some of its other derivatives have been analyzed by high performance liquid chromatography (Iwaki et al., 1996; Manceau et al., 1992) and gas chromatography and gas chromatography-mass spectrometry (Zoellner, 1994). The HPLC method was employed to study the bioconversion of nicotinic acid to nornicotine in biological matrices such as blood plasma and urine (Manceau et al., 1992). The GC and GC-MS methods have been used to investigate the structural fragmentation patterns of the mono and diacylglycerol derivatives of nicotinic acid (Zoellner, 1994).

The purpose of the present research was to develop an acceptable analytical method for the separation and quantification of several dihalonicotinic acids in a mixture using GC and GC-MS techniques. Four methyl esterification methods, well-documented in the literature, were compared in terms of GC sensitivity, effficiency, and analysis time using six dihalonicotinic acids in a mixture as a test sample, as listed in Fig. 1. The methods used were (1) HC1/methanol, (2) BF_3/methanol, (3) Dicyclohexylcarbodiimide/methanol, and (4) diazomethane. These methods are commonly used for the methyl esterification of a variety of aliphatic and aromatic acids. Method #4 has been used earlier to synthesize the methyl esters of eight dihalonicotinic acids (Setliff and Huie, 1981). The conversion into the esters was about eighty percent in most cases. However, halogen replacement by chlorine at 2- and 6- positions from HC1 produced in-situ was observed for some esters when the preparation of the esters was attempted by reacting the dihalonicotinic acids with $SOC1_2$ and methanol.

Analysis of a Mixture of Several Dihalonicotinic Acids by Gas Chromatography and Gas Chromatography-Mass Spectrometry

SIX DIHALONICOTINIC ACIDS USED FOR ANALYSIS



X	Y	Z	COMPOUND NAME
Cl	H	Cl	2,5-dichloronicotinic acid
Br	H	Cl	5-bromo-2-chloronicotinic acid
Br	H	Br	2,5-dibromonicotinic acid
Cl	Cl	H	5,6-dichloronicotinic acid
Br	Cl	H	5-bromo-6-chloronicotinic acid
Br	Br	H	5,6-dibromonicotinic acid

Table 1: The six dihalonicotinic acids used for the analysis.

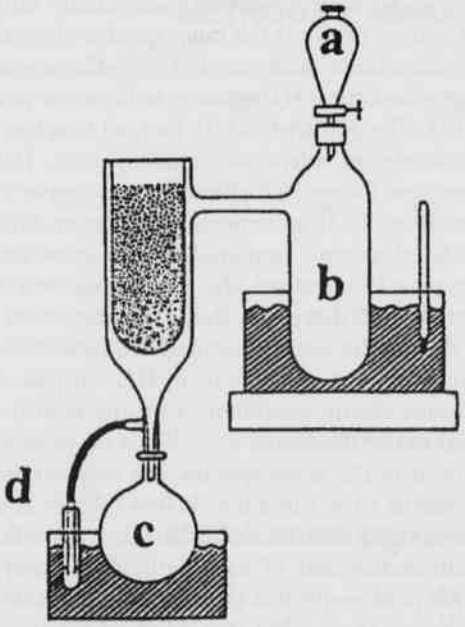


Fig. 1. Mini diazald apparatus and its set-up to produce diazomethane. The four components of the set-up are: a - a 100 mL separatory fumlel with a teflon stopcock and stopper; b - the mini diazald apparatus, consisting of a reaction vessel and condenser in one compact piece; c - a 50 mL round bottom flask; d - an ether trap at the side arm.

In general, esterification is necessary for the GC analysis of organic acids in order to increase the volatility of the test compounds so that they will be more amenable to separation in a GC column with little or no peak-tailing. The success of a method depends largely on the structures of the acids, and to some extent on their solubilities and other physical characteristics. It is imperative, therefore, to attempt various methods in order to develop the most suitable analytical method for a class of compounds.

Materials and Methods

A Varian Model 3400 gas chromatograph, coupled with a flame-ionization detector, was used to perform the GC analysis of the compounds. The GC-MS analyses were conducted with a Varian 3400 GC coupled with a Varian Saturn II Ion-Trap Detector, and also with a Hewlett-Packard Model 5890 Series II GC with a Hewlett-Packard Model 5970 Mass Selective (Quadrupole) Detector. Further details on the experimental conditions for data collection are provided later with the gas chromatograms and the mass spectra.

A mini-diazald kit (Aldrich Chemical) was used to prepare minute amounts of diazomethane from diazald (N-methyl-N-nitroso-p-toluenesulfonamide) for the esterification of the test compounds (Method #4). Standard laboratory glassware was used for all other esterification and sample preparation. All solvents and reagents were of analytical grade. Hydrochloric acid, benzene, dicyclohexylcarbodiimide (DCC), diethylether (99.9% pure, HPLC grade) and sulfuric acid were obtained from Sigma-Aldrich, whereas methanol, methylene chloride and pyridine were purchased from Fisher Scientific. The six test compounds were provided as analytical samples by F.L. Setliff of our department. The procedures for the esterification methods are given below:

(1) Method #1: HCl/Methanol Esterification (Knapp, 1979) - The samples (1.0 to 10.0 mg each) were dissolved in 4.0 mL of 0.50 M HCl in methanol to which 0.50 mL benzene was added. The solution was heated at 80°C for an hour with frequent shaking, cooled to room temperature, and then 10 mL of distilled water was added to it. The resultant esters were extracted three times with 3.0 mL of diethylether. The ether extract was dried over a 4:1 (w/w) mixture of anhydrous Na_2SO_4/$NaHCO_3$. Because of the interference from HCl, as will be described later, the aforementioned standard method was modified by replacing HCl with H_2SO_4. The methyl ester crystals obtained were then dissolved in 3.0 mL of methylene chloride. The solution was refrigerated until ready to analyze by GC and GC-MS.

(2) Method #2: BF_3/Methanol Esterification (Knapp, 1979) - The samples (10.0 mg each) were dissolved in 3.0 mL of methanol to which 3.0 mL of a 50% BF_3 in methanol solu-

tion (obtained from Sigma Chemicals) was added. The solution was refluxed at 100°C for ten minutes. Excess methanol was removed under vacuum at room temperature. After 20.0 mL of distilled water was added, the solution was shaken vigorously for five minutes. The layers were allowed to separate. The top layer contained most of the methyl esters. The acidic aqueous bottom layer was extracted three times with 10 mL of diethylether. The ether extracts were mixed and then were evaporated under vacuum at room temperature. The methyl esters were then dissolved in enough methylene chloride to bring the final volume up to 1.0 mL.

(3) Method #3: DCC/Methanol Esterification (Knapp, 1979) - The samples (10.0 mg each) were dissolved in a solution containing 4.0 mL of methanol and 1.0 mL of pyridine, the latter being the catalyst. The DCC was added in excess (10.52 mg), and the resulting solution was heated to about 80°C with gentle stirring for thirty minutes. The reaction produced N,N'-dicyclohexylurea as a byproduct, which was allowed to settle at the bottom and was decanted off. The excess DCC was decomposed at the end of esterification by adding acetic acid. The supernatant liquid, containing the methyl esters, was evaporated to dryness under vacuum, and the crystals then dissolved in enough methylene chloride to make a 1.0 mL solution for GC and GC-MS analysis.

(4) Method #4: Diazomethane Esterification (Aldrich Chemical, 1990)–The minidiazald kit was assembled according to the instruction provided by the manufacturer, as shown in Fig. 1. The condenser was filled with dry ice, then acetone was added slowly until the cold finger was about one-third full. Ethanol (5.0 mL) was added to a solution of KOH (2.5 g) in 4.0 mL of distilled water in the reaction vessel. A 50.0 mL receiving flask (with clear-seal joint) was attached to the condenser and then cooled in an ice bath. The trap, which had approximately 2 mL of diethylether, was cooled in an ice:salt (3:1) bath, which was also used for the receiver. A separatory funnel (with clear-seal joint) was placed over the reaction vessel, and the funnel was charged with a solution of diazald (2.5 g, 11.5 mmol) in 22.5 mL of diethylether. The reaction vessel was heated in a water bath at 65°C, and the diazald solution was added in small amounts periodically over a period of twenty minutes. The rate of addition of diazald solution was about the same as the rate of distillation. The cold finger was replenished with dry ice as necessary. When all of the diazald was consumed, 10.0 mL of diethylether were slowly added, and the distillation was continued until the distillate was colorless. The diethylether distillate should have contained about 350 mg (8.3 mmol) of diazomethane. The diazomethane was kept in a freezer at 0°C until its use for the esterication of the samples.

For the esterification, the samples (10.0 mg each) were dissolved in 1.0 mL of methylene chloride to which the diazomethane solution was added dropwise until a light yellow color persisted, thus insuring complete conversion of the test compounds into their corresponding methyl esters. In general, about 1.5 mL of diazomethane solution was necessary to complete the reaction. The resulting solution was allowed to stand overnight to insure complete reaction and the decomposition of the excess (if any) diazomethane. The sample solutions were then refrigerated until the GC and GC-MS analysis.

Results and Discussion

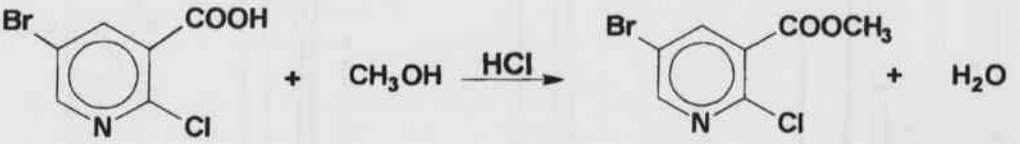
While a large number of methods for the esterification of organic acids is available in the literature, the four chosen are, in general, very successful in terms of high percentage of esterification, fast conversion rate, and the ease of carrying out the reactions. The chemistry involved in these methods are shown in Table 2, with 5-bromo-2-chloronicotinic acid as the test compound.

In Method #1, involving HCl (or H_2SO_4) and methanol, four of the six test compounds (5-bromo-6-chloro-; 2,5-dibromo-; 5,6-dibromo-; and 5-bromo-2-chloronicotinic acids) were esterified individually and also in a mixture. Figure 2 presents the mass spectra of methyl 5-bromo-6-chloronicotinate and methyl 2,5-dibromonicotinate. The spectra look almost the same, with major peaks at m/z: 76, 110, 170, 192, 220 and 251. In fact, all four test compounds showed almost identical mass spectra. Both 5-bromo-2-chloro- and 5-bromo-6-chloro-isomers gave a large parent ion peak at m/z 249 as expected. However, both 2,5-dibromo- and 5,6-dibromo- isomers failed to show the parent ion peak at m/z 293; instead, the major peak was at m/z 249. It was concluded, therefore, that a displacement reaction occurred during the esterification of the latter two compounds, during which the chlorine from HCl displaced one of the two bromine atoms, producing a bromo-chloro- compound identical to the first two esters. Since no peak at m/z 205 was observed in the mass spectra, the displacement of both bromine atoms were ruled out. When sulfuric acid was used instead of hydrochloric acid in the esterification process, the chromatogram of each individual compound showed multiple peaks with less than quantitative esterification. Therefore, it was decided that Method #1 would be unsuitable for a quantitative method development.

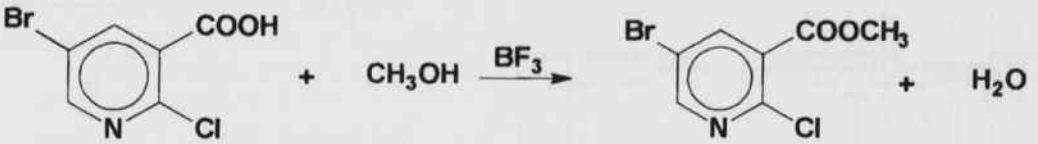
When BF_3/methanol was used for esterification (Method #2), incomplete esterification was evident. Figure 3 shows the chromatogram obtained when 5,6-dibromonicotinic acid was esterified by this method, indicating the presence of two compounds in the reaction product. GC-MS study revealed that the first peak was due to the unconverted acid, whereas the second one was an esterified product of the acid; only about 60% conversion was noted. When a

CHEMISTRY OF VARIOUS METHODS OF ESTERIFICATION

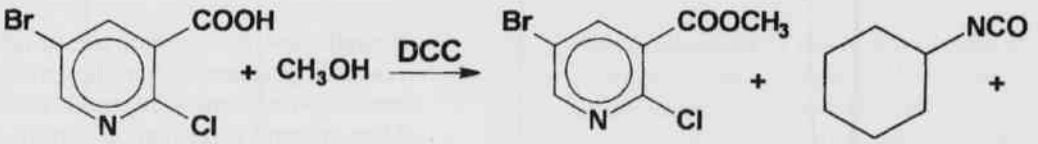
METHOD #1: Methanol and Hydrochloric Acid (or Sulfuric Acid).

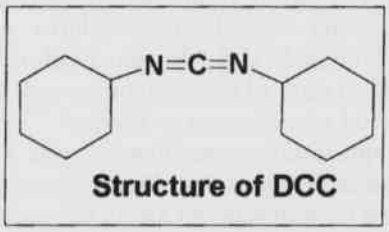


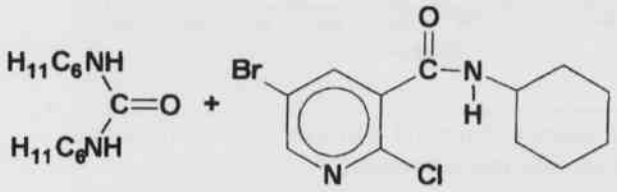
METHOD #2: Methanol and Boron Trifluoride.



METHOD #3: Methanol and Dicyclohexylcarbodiimide.







METHOD #4: Diazomethane Produced form Diazald.

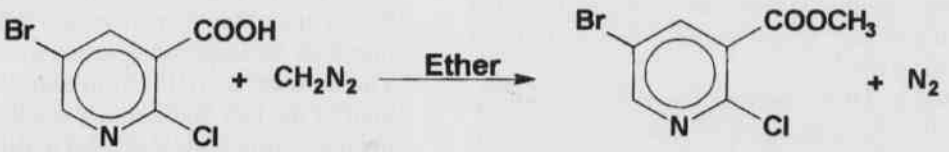


Table 2: Chemistry of the various methods of esterification.

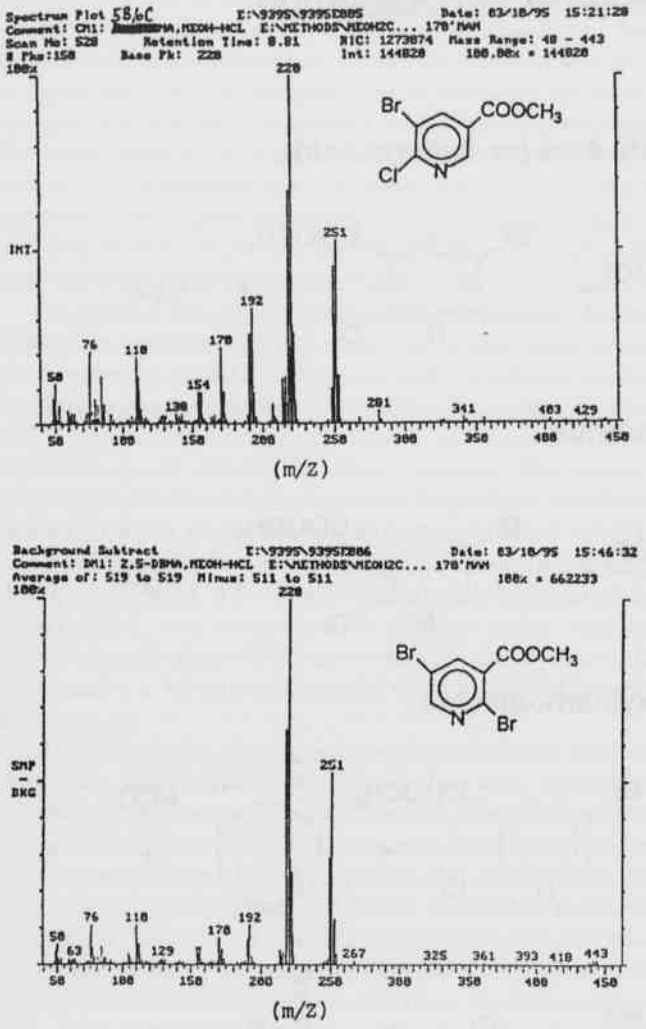


Fig. 2. Mass spectra of methyl 5-bromo-6-chloronicotinate and methyl 2,5-dibromo nicotinate.

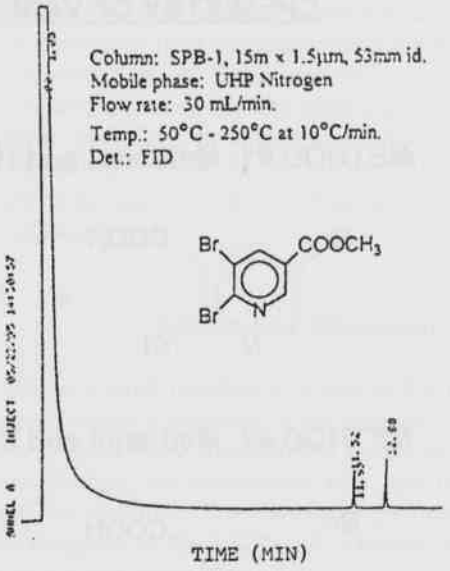


Fig. 3. Chromatogram of the reaction products following the esterification of 5,6-dibromonicotinic acid with BF_3/ methanol.

mixture of all four test compounds was esterified, the total ion chromatogram showed eight peaks, indicating an incomplete conversion of the acids. In addition, the mass spectra of some of the esters indicated the displacement of halogens by methoxy groups. For example, the esterification of 5-bromo-6-chloronicotinic acid resulted in the formation of methyl 5-bromo-6-methoxynicotinate instead of methyl 5-bromo-6-chloronicotinate. Consequently, this method of esterification was discarded.

When subjected to DCC/methanol/pyridine esterification (Method #3), the chromatogram of 5-bromo-2-chloronicotinic acid produced multiple peaks (Fig. 4). As many as five peaks were obtained (excluding the solvent peak) from a single test compound, presumably due to a number of reaction products. After the product of this reaction was treated with acetic acid, there were still four peaks visible. Mass spectral investigation confirmed that a number of side reactions occurred, resulting in the formation of isocyanatocyclohexane, N,N'-dicyclohexylurea and its protonated form, N(cyclohexyl)-5-bromo-2-chloronicotinamide, and the methyl ester of the test compound. Obviously, this was not a good esterification technique.

A quantitative esterification was achieved using diazomethane (Method #4). Figure 5 shows a chromatogram obtained for a mixture of all six test compounds, along with 2-chlorobenzoic acid as the internal standard (at 12.26 min). One notices that only six peaks, well-resolved, were obtained with no indication of any side reaction. Mass spectral investigation of each of the peaks revealed the identity of the compounds as indicated on the chromatogram (Fig. 5); there was no evidence of mixed products in any of the peaks. Moreover, a comparative study, using purified standards from a previous study (Setliff and Huie, 1981) showed that a quantitative conversion ofthe dihalonicotinic acids into their corresponding esters was achieved by this method. The increase in yield (from about 80% to 100%) was attributed to the fact that a much smaller quantity (1.0 -10 mg) of the test compounds was used in the present study. The small peak preceding the chlorobenzoic acid peak was due to an

Analysis of a Mixture of Several Dihalonicotinic Acids by Gas Chromatography and Gas Chromatography-Mass Spectrometry

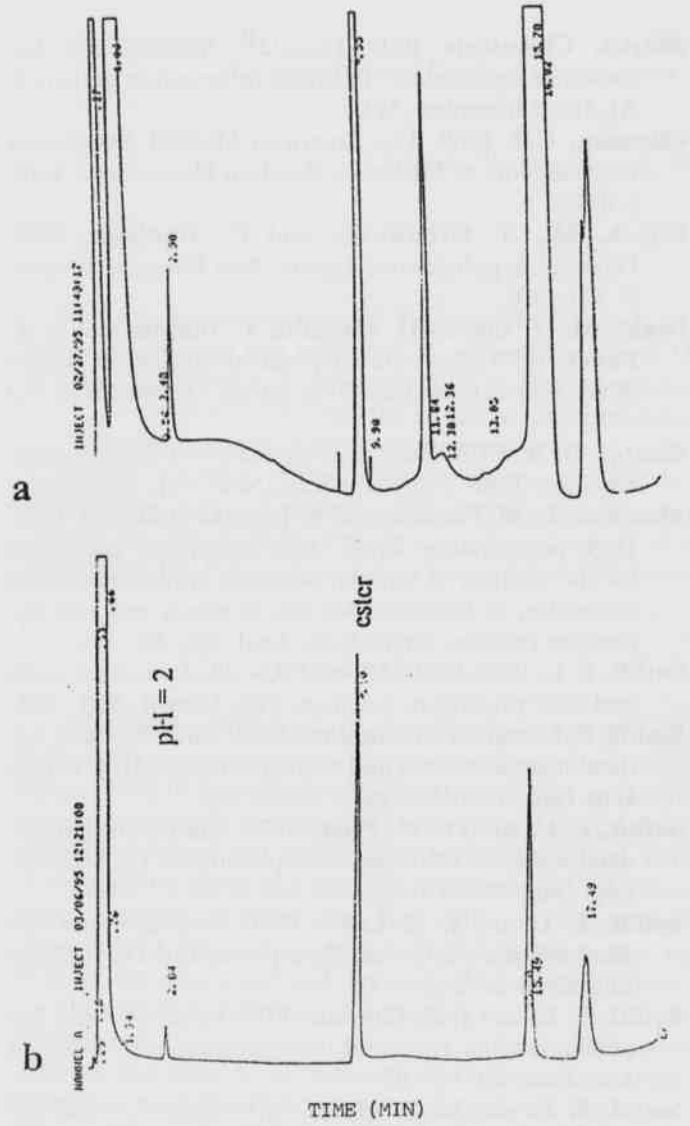


Fig. 4. Chromatograms of the reaction products following the esterification of 5-bromo-2-chloronicotinic acid using DCC/ methanol; a - chromatogram obtained at the reaction pH; b - chromatogram after the acidification. The chromatographic conditions are similar to those in Fig. 3.

impurity in the internal standard (used without purification) which was not identified. All six test compounds were also esterified individually to confirm their retention times and the order of elution from the GC column, which agreed with those obtained for the mixture. Both GC and GC-MS studies used identical column and separation parameters as described in Fig. 5.

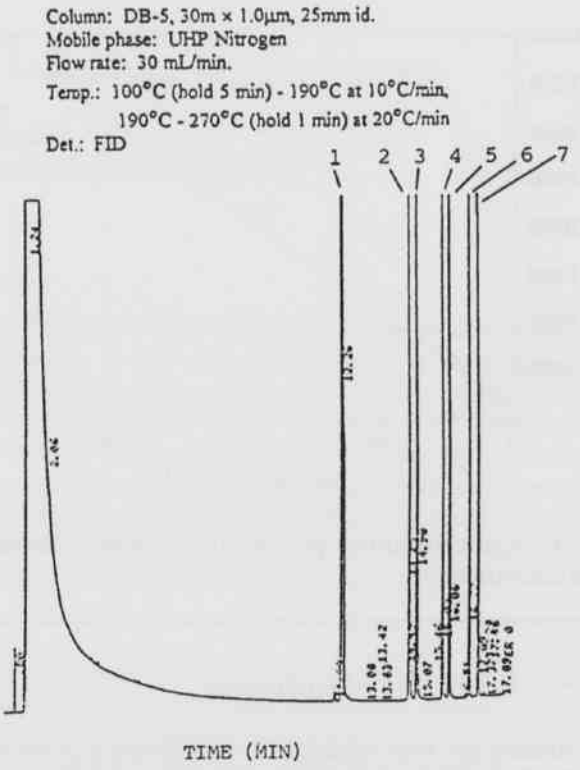


Fig. 5. Chromatograms of the methyl esters of the mixture of six test compounds by diazomethane esterification. The peaks are identified as follows: (1) methyl 2-chlorobenzoate (internal standard); (2) methyl 2,5dichloronicotinate; (3) methyl 5,6-dichloronicotinate; (4) methyl 5-bromo2-chloronicotinate; (5) methyl 5-bromo-6-chloronicotinate; (6) methyl 2,5dibromonicotinate; (7) methyl 5,6-dibromonicotinate.

It is obvious that Method #4 meets the criteria of a good analytical method for the separation and quantification of the dihalonicotinic acids. The methyl esters were produced quantitatively and the GC peaks were well-resolved. Since other dihalonicotinic acids were not readily available, the method development was continued using only those six test compounds. The concentration profile for each compound was studied both individually as well as in a mixture, ranging from 2 ng/µL to 1000 ng/µL. A typical plot of the data is shown in Fig. 6. Excellent linearity was observed up to about 500 ng/µL, above which the detector response was lower than expected. From these graphs the detection limit was estimated to be about 1 ng/µL. The reproducibility for the analysis in triplicate showed relative standard deviation between 5 and 15% for the compounds.

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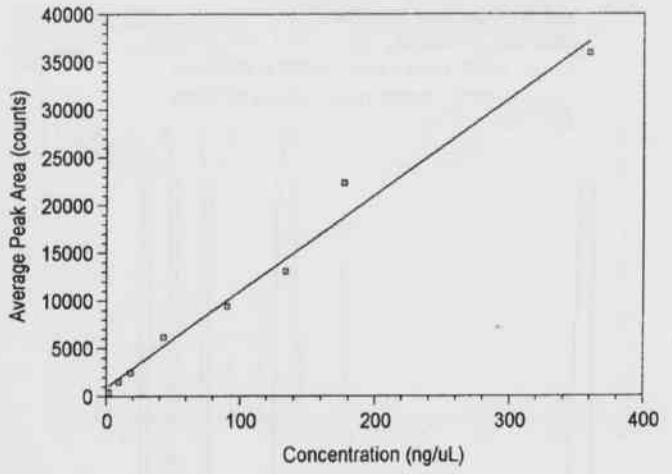

Fig. 6. Concentration profile of methyl 5-bromo-2-chloronicotinate.

Conclusions

Among the four methods of esterification studied, the one involving diazomethane was the only suitable technique for the separation and quantification of the dihalonicotinic acids. The method provided short analysis time with all six methyldihalonicotinates eluting within nineteen minutes. The methyl esters left no "memory effect" from the column, as compared to those observed with unesterified dihalonicotinic acids; in the latter cases, the column needed to be flushed repeatedly with methylene chloride to remove the traces of the compounds. The methyl ester peaks were also much sharper than the original acid peaks, with no tailing. We are confident that this method would yield separation and quantification of all twenty-six dihalonicotinic acids when they are present in a mixture. Lack of availability of all those test compounds prevented us from attempting such a separation at the present time. However, the observed pattern of elution of the methyl esters is that the 2,5- isomer is preceded by the 5,6- isomer of each methyldihalonicotinate. Also, among various dihalonicotinates, the dichloro esters elute before the bromo-chloro esters, which are followed by dibromo esters. Our future plan includes the use of all twenty-six dihalonicotinic acids in a sample. Also, an electron-capture detector will be used to improve the sensitivity and the detection limit of the method.

ACKNOWLEDGMENTS.—The authors wish to thank Mr. Tom Heinz of the National Center for Toxicological Research, Jefferson, AR for his help in obtaining some preliminary GC-MS data and their interpretation.

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A Description of the Sections and Subsections of the Interior Highlands of Arkansas and Oklahoma

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Abstract

Sections and subsections of the Interior Highlands of Arkansas and Oklahoma are redefined, mapped and briefly summarized. The map was produced to support the Ozark-Ouachita Highlands Assessment (OOHA), being conducted by the USDA Forest Service. It revises the USDA Forest Service map "Ecological units of the eastern United States, first approximation" by Keys et al. (1995) and the earlier maps of the natural divisions of Arkansas (Foti, 1974; Foti, 1976; Pell, 1983) to reflect new knowledge and to achieve consistency with units recognized in Missouri. Four sections (natural divisions) are defined as opposed to the three of the previous Arkansas natural divisions maps, and new subsections are recognized within most sections. Digital maps of geology, soils and topography were used to create the map in ARC/INFO. The map is accessible through the World Wide Web as a portion of a map of the entire Interior Highlands region of Arkansas, Oklahoma and Missouri on the home page of the Ouachita National Forest at http://www.fs.fed.us/oonf/ooha/welcome.htm.

Introduction

The Interior Highlands has long been recognized as a distinct physiographic and natural region (Fenneman, 1938; Braun, 1950). It is generally characterized as hilly to mountainous topography on paleozoic substrates dominated by upland hardwood and upland pine-hardwood forests. It is surrounded by plains that are lower in elevation with more recent geological substrates and different vegetation. Vegetation of these plains ranges from tallgrass prairie to lowland pine-hardwood and bottomland hardwood forests.

Even though the Interior Highlands region has consistent general characteristics, there are striking differences within it that may occur within distinct geographic areas. Therefore, most descriptions and studies divide the region into smaller, more uniform areas. Authors have generally recognized at least two provinces, the Ozark Mountains and the Ouachita Mountains (Croneis, 1930; Fenneman, 1938; Braun, 1950; Thornbury, 1965; Foti, 1974). Sometimes the Arkansas Valley has been considered a separate province or natural division (Foti, 1976; Pell, 1983; Omernik, 1987). In addition, Omernik (1987) recognized the Boston Mountains as an ecoregion (natural division); previous authors had considered it a subdivision of the Ozark Mountains. These provinces are often subdivided as well (Fig. 1).

In order to facilitate agency ecosystem management efforts, the Forest Service developed a new national regionalization framework (Keys et al., 1995; henceforth referred to as Keys et al. Or the Keys map; Fig. 2) based on a national map of ecosystems of North America by Bailey et al. (1994). The new framework is hierarchical like older efforts but is based on a more holistic consideration of landscape properties than some earlier maps, with climate and soil playing prominent roles along with physiography. The new framework is also explicitly designed to rationally subdivide landscapes down to levels meaningful in ecosystem management, i.e. to units of several acres to a few tens of acres. The older and newer maps coincide most closely at the level of Section (Keys et al., Fig. 2), Province (Fenneman, 1938) and Natural Division (Foti, 1974). Although differences occur at this level, they are usually in the form of one unit in one system equating to two units in another system. The new framework is often more detailed at lower levels in the hierarchy than older maps.

The USDA Forest Service has currently underway a project termed the Ozark-Ouachita Highlands Assessment (OOHA; USDA Forest Service, in prep.) that is an attempt to characterize the Interior Highlands region as a whole in order to support revision of Forest Plans on the three National Forests within the region: The Ouachita, the Ozark-St. Francis and the Mark Twain national forests. It was necessary to define regions within the Highlands that were distinct enough to require different management plans. In order to maintain national consistency the OOHA assumed from the outset that the Keys map would provide the regional perspective.

Methods

Examination of the Keys map (Fig. 2) and comparison with other regional maps such as the Croneis map (1930, Fig. 1) and geological and topographical base maps revealed that sections and subsections and their boundaries are not consistently meaningful and accurate across the assessment

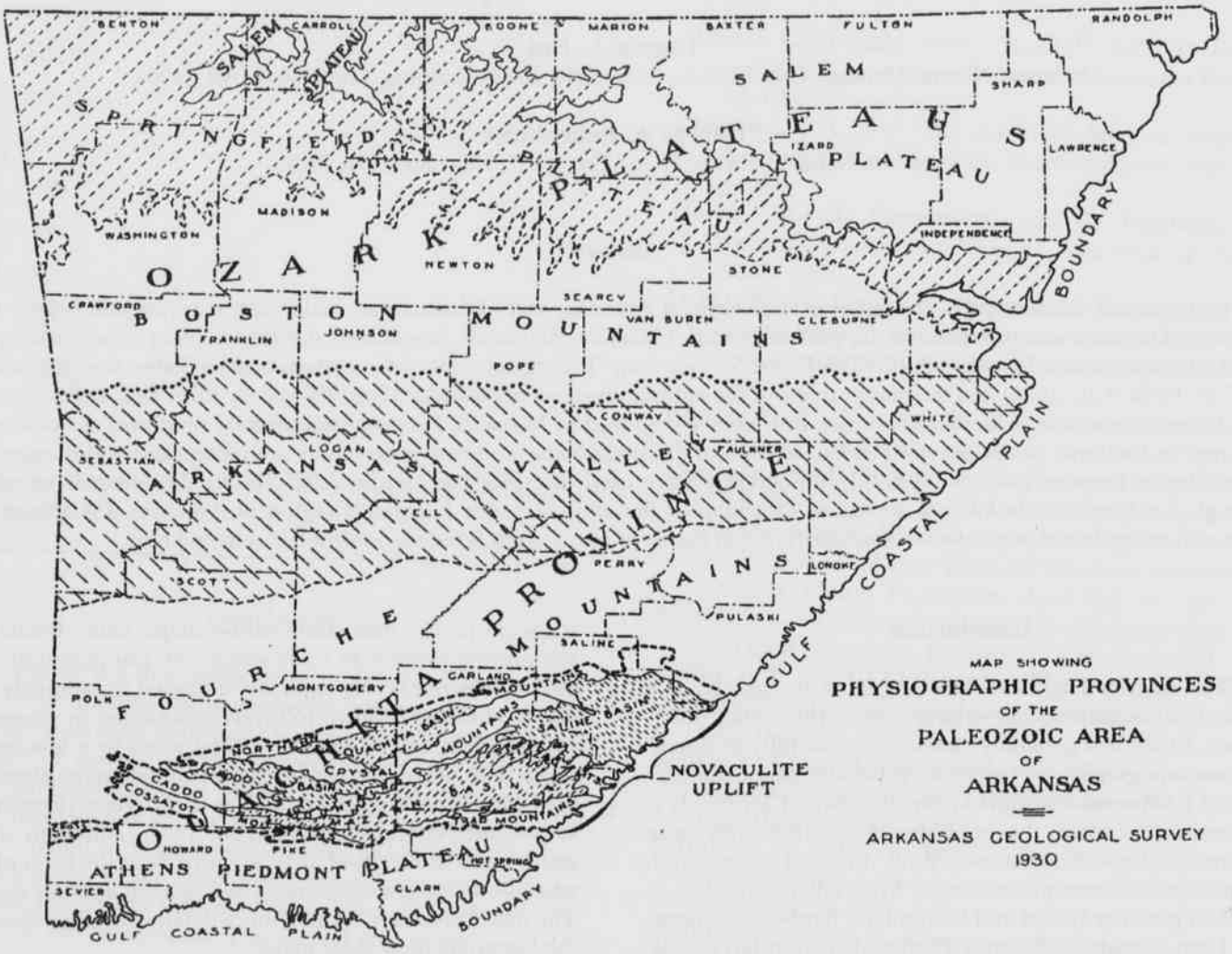

Fig. 1. Map of physiographic provinces of Arkansas developed by Croneis (1930).

area. The Missouri units and their boundaries have been settled for years, so the Keys map simply adopted those, and changes needed for the assessment were very minor. In contrast, the Arkansas units and boundaries required considerable revision because the Keys et al. approach is substantially different from what was done in the past (Croneis, 1930; Foti, 1974) and locally-created maps were not available. The Keys map is of lower quality in Oklahoma because in that state only general regions have been defined (Oklahoma Biodiversity Task Force, 1996); boundaries are not detailed and subdivisions are not mapped. Furthermore the Keys map appears to be derived from low-detail base maps, and boundaries were judged to be too general for OOHA purposes. The Keys map does not explicitly define the source or rationale for boundaries, so revision of the map sometimes required a determination of the defining physical feature and use of an appropriate base map.

Rationales for many regional boundaries in Arkansas have been presented by Croneis (1930) and Foti (1974) and were adopted for this revision. Rationales for new boundaries are presented here. All boundaries are based on either geology or topography, although soils maps were used for comparison in some cases. The geologic base map was the 1:2,500,000 scale geology of the conterminous U.S. (Schruben et al., 1994); no larger scale geologic map covering the entire assessment area was available. The topographic base map was created for this project from 30-m USGS digital elevation model files by the Spatial Analysis Laboratory of the School of Forest Resources, University of Arkansas at Monticello.

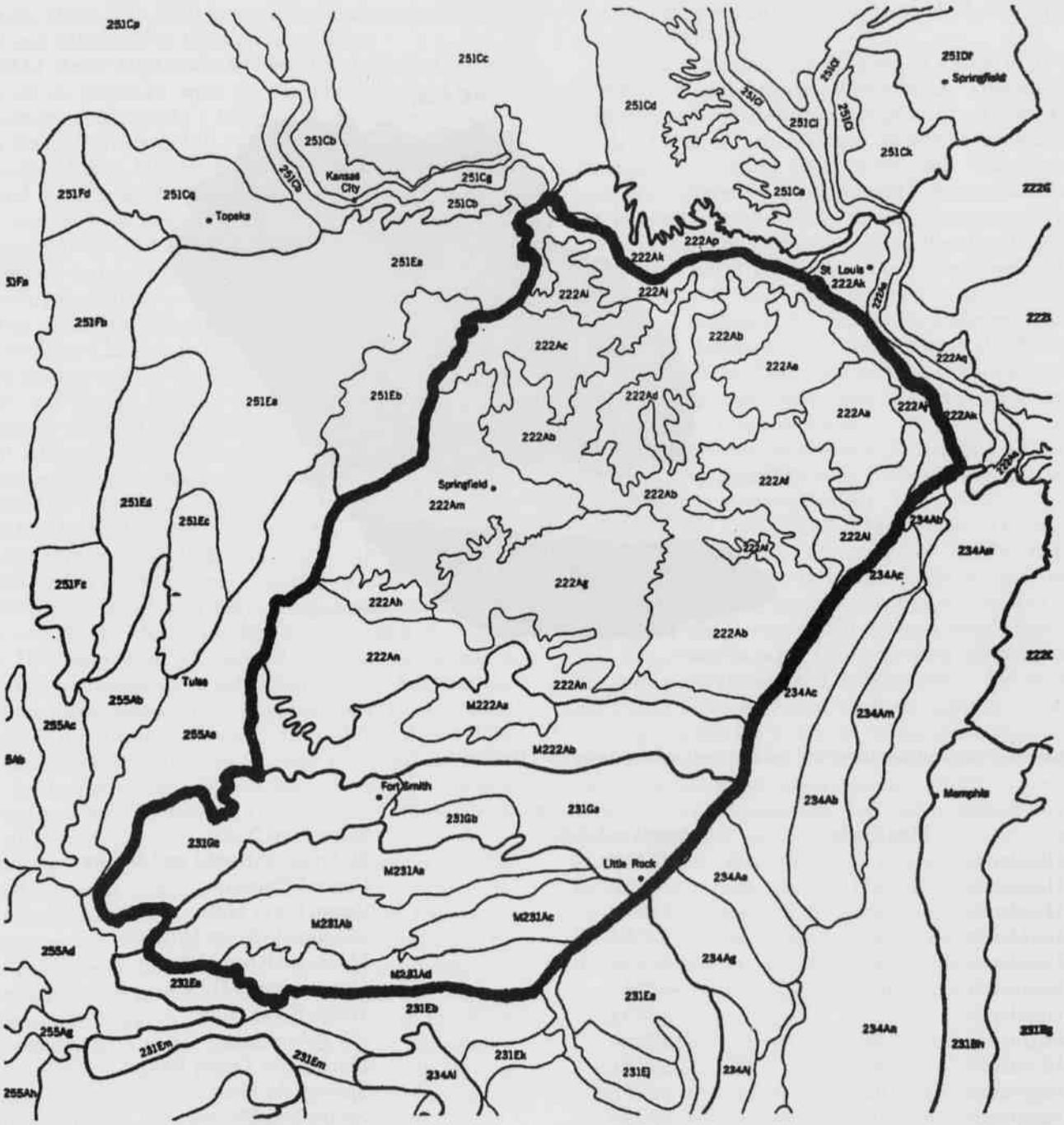

Fig. 2. Keys et al. (1995) Sections and subsections of the Interior Highlands region. See Fig. 3. for legend.

Results

A new map of the sections and subsections of the Interior Highlands was created that was based on the ecological unit definitions of the Keys map but used boundary definitions of Croneis (1930), Foti (1974) or those presented here (Fig. 3, Fig. 4). The map is in digital form and may be accessed at http://www.fs.fed.us/oonf/ooha/welcome.htm

The following discussion describes the ecological units used in the OOHA and the factors on which the boundaries were based, along with changes from the Keys map. Alphanumeric codes used here are from the Keys map.

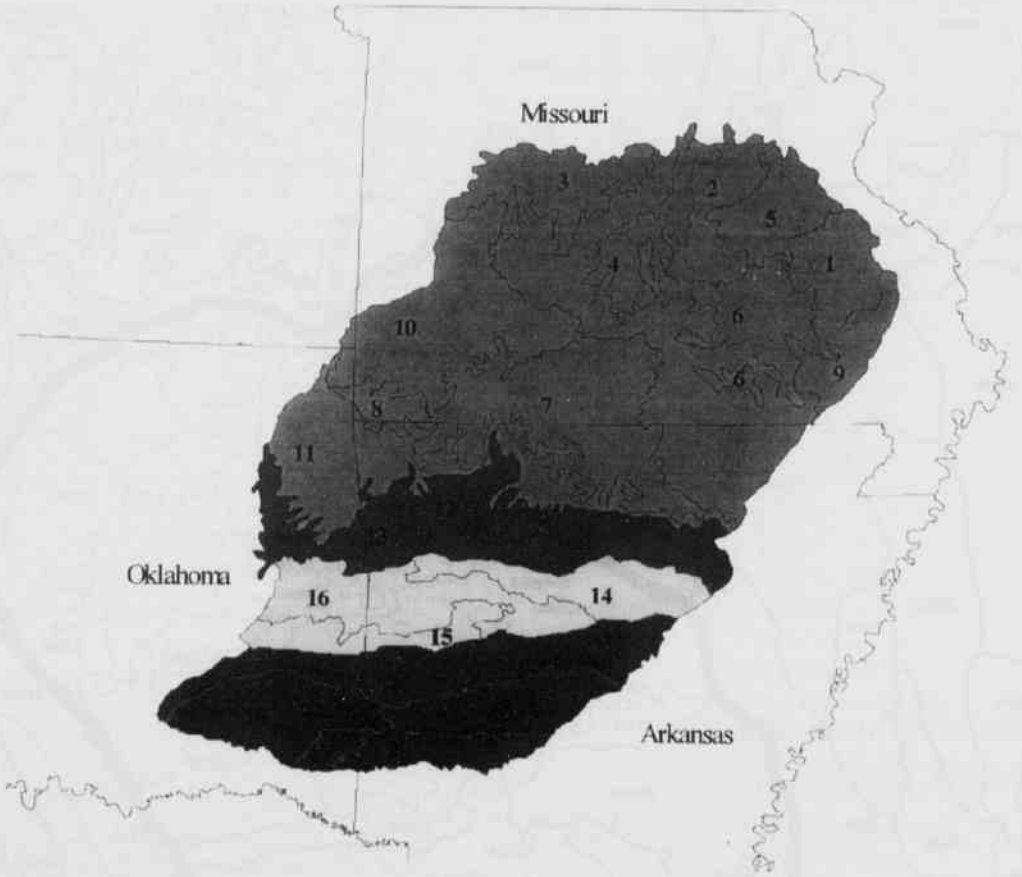

Fig. 3. Revised map of sections and subsections of the Interior Highlands.

Legend

Section	Map Code	Subsection Code	Subsection Name
Ozark Highlands	1	222Aa	St. Francois Knobs and Basins
Ozark Highlands	2	222Ab	Central Plateau
Ozark Highlands	3	222Ac	Osage River Hills
Ozark Highlands	4	222Ad	Gasconade River Hills
Ozark Highlands	5	222Ae	Meramec River Hills
Ozark Highlands	6	222Af	Current River Hills
Ozark Highlands	7	222Ag	White River Hills
Ozark Highlands	8	222Ah	Elk River Hills
Ozark Highlands	9	222Al	Black River Ozark Border
Ozark Highlands	10	222Am	Springfield Plain
Ozark Highlands	11	222An	Springfield Plateua
Boston Mountains	12	M222Aa	Upper Boston Mountains
Boston Mountains	13	M222Ab	Lower Boston Mountains
Arkansas Valley	14	231Ga	Eastern Arkansas Valley
Arkansas Valley	15	231Gb	Western Arkansas Valley Mountains
Arkansas Valley	16	231Gc	Western Arkansas Valley
Ouachita MountaIns	17	M231Aa	Fourche Mountains
Ouachita Mountains	18	M231Ab	Western Ouachita Mountains
Ouachita Mountains	19	M231Ac	Central Ouachita Mountains
Ouachita Mountains	20	M231Ad	Athens Piedmont Plateau

Changes in Arkansas subsections from previous treatments (Croneis, 1930; Foti, 1974) are noted. All subsections recognized and delineated in Oklahoma are new.

222A Ozark Highlands Section.--The following subsections, all in Missouri, were not included in the OOHA Assessment area: 222Ai - Prairie Ozark Border; 222Aj - Inner Ozark Border; 222Ak - Outer Ozark Border; 222Ao - Mississippi River Alluvial Plain; 222Ap - Missouri River Alluvial Plain; and 222 Aq - Illinois Ozarks (Fig. 2). These were excluded because they are on the periphery of the region, are not included in some data sets being used in the assessment, and include additional states and/or St. Louis, whose large population would skew socioeconomic analysis.

The following subsections, all in Missouri, are not described here, but are in the OOHA area, were described in that project, and are shown in Fig. 2: 222Aa - St. Francois Knobs and Basins; 222Ac - Osage River Hills; 222Ad - Gasconade River Hills; 222Ae - Meramec River Hills; 222Af - Current River Hills; 222Al - Black River Ozark Border; and 222Am - Springfield Plain.

222Ab - Central Plateau - Occurs in Missouri (2,025,986 ha) and Arkansas (540,337 ha), and is comprised of irregular plains 90-500 m in elevation with karst features on Ordovician cherty dolomite, sandstone and cherty clay residuum are covered with prairies, oak woodlands and dry-mesic oak forests. The Keys map boundary with the White River Hills subsection was altered to follow the break in topography between these subsections where land surface elevation drops steeply from the relatively level Central Plateau to the downcut streams of the White River Hills. Thus the Central Plateau stands above the White River Hills. As compared with earlier Arkansas maps, this is a new subdivision of the Salem Plateau subdivision (Croneis, 1930; Foti, 1974).

222Ag - White River Hills - Occurs in Missouri (872,470 ha) and Arkansas (638,270 ha). Hills with entrenched valleys, 180-500 m in elevation, with karst features, formed by downcutting of White River tributaries are underlain by Ordovician cherty dolomite with cherty clay residuum covered with alkaline glades and oak woodlands and forests. Changes were made in the Arkansas portion of the Keys map boundaries to better follow the break in topography from the surrounding plains. Compared with earlier Arkansas maps, this is a new subdivision of the Salem Plateau subdivision (Croneis, 1930; Foti, 1974).

222Ah - Elk River Hills - Occurs in Missouri (22,794 ha) and Arkansas (23,242 ha). Hills with entrenched valleys, 270-425 m in elevation, with karst features, formed by streams downcutting to the Neosho River underlain by Mississippian cherty limestone with cherty clay residuum are covered with oak woodlands and forests. Changes were made in the Arkansas portion of the Keys map boundaries to better follow the break in topography from the surrounding subsections. Compared with earlier Arkansas maps, this is a new subdivision of the Springfield Plateau subdivision (Croneis, 1930; Foti, 1974).

222An - Springfield Plateau - Occurs in Oklahoma (601,645 ha) and Arkansas (639,330 ha). This subsection is characterized by smooth to irregular plains with karst features, 240-425 m in elevation, underlain by Mississippian limestone sometimes very cherty and with cherty clay residuum covered with prairie and oak woodlands and forest, alkaline and acid glades. Detail changes were made in the Keys map boundaries to better follow the drop in elevations to the Elk River Hills and to more closely follow the boundaries with older and younger geological substrates throughout the rest of the subsection perimeter. Compared with earlier Arkansas maps, this is identical with the traditional Springfield Plateau subdivision (Croneis, 1930; Foti, 1974) except for the elimination of a small area now within the Elk River Hills subsection.

M222A Boston Mountains Section.--In earlier maps, with the exception of Omernik (1987), this section was treated as a subsection or equivalent.

M222Aa - Upper Boston Mountains - Occurs only in Arkansas (447,836 ha). Low mountains 300-825 m in elevation, underlain by Pennsylvanian sandstone and shale with sandy residuum and loamy colluvium are covered with oak woodlands and forests. Detail changes were made in Keys map boundaries to better follow the geologic boundary with the Springfield Plateau and to better follow the corresponding Ozark National Forest landtype association boundary elsewhere along the perimeter of the subsection. This subsection was defined on the basis of elevation (that approximates the 550 m elevation contour), which corresponds to areas of lower temperature and higher rainfall and consequent changes in plant community composition. The Keys et al. names for this subsection (Boston Mountains) and the following subsection (Boston Hills) were changed to reflect that both are parts of the vernacular and physiographic Boston Mountains. Compared with earlier Arkansas maps, the Upper Boston Mountains Subsection is a new subdivision of the Boston Mountain subdivision (Croneis, 1930; Foti, 1974).

M222Ab - Lower Boston Mountains - Occurs in Oklahoma (337,727 ha) and Arkansas (1,000247 ha). High hills, 150-550 m in elevation, underlain by Pennsylvanian sandstone and shale with sandy residuum and loamy colluvium are covered with pine-oak and oak woodlands and forests. Detail changes were made in Keys map boundaries to better follow the corresponding Ozark National Forest landtype association boundary with the Upper Boston Mountains and to better follow the boundary with younger and older geologic substrates elsewhere along the northern, eastern and western perimeter of the subsection and topographically-defined southern boundary (the escarpment to

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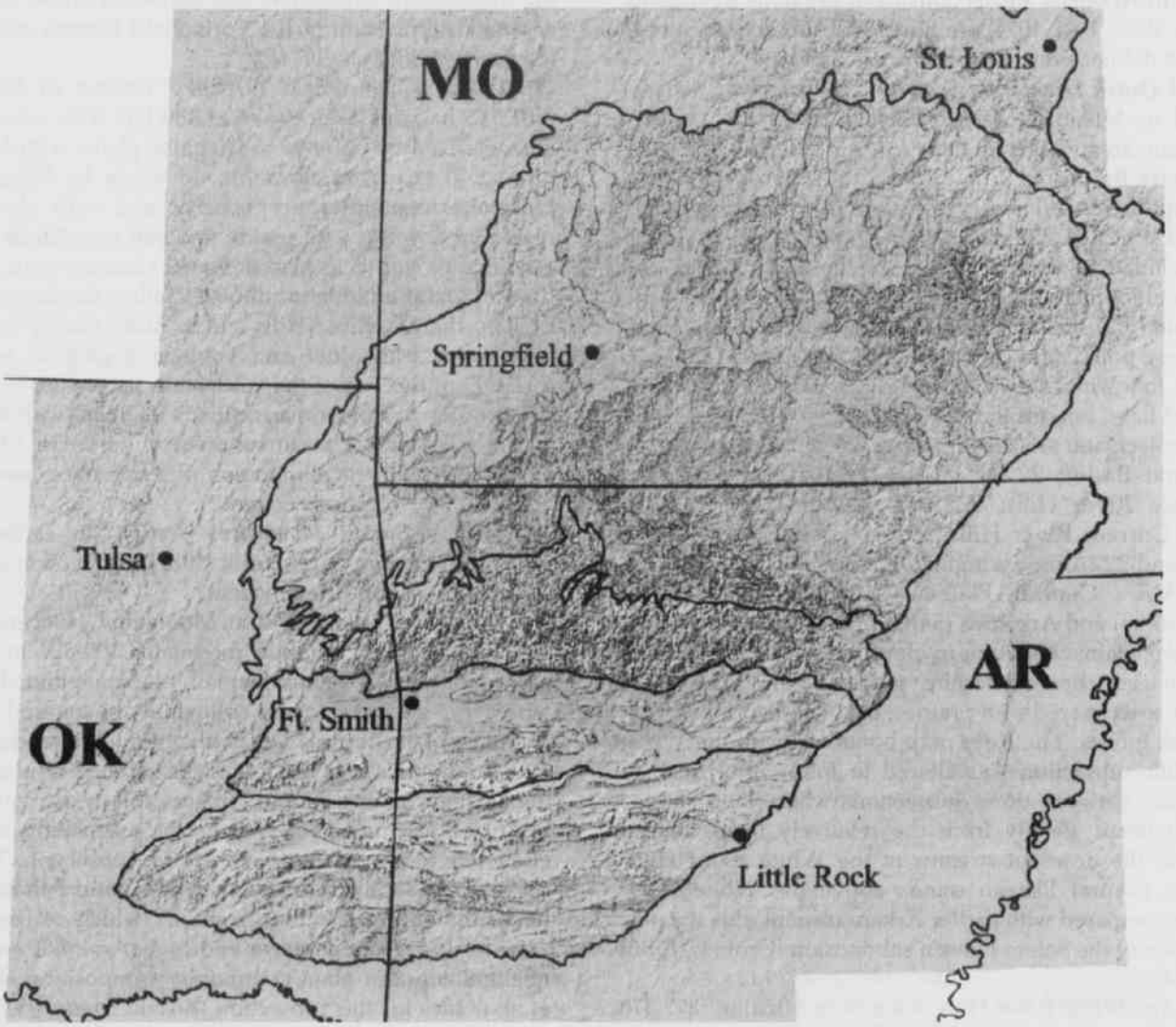

Fig. 4. Sections and subsections of the Interior Highlands shown on shaded relief background.

the Arkansas Valley Section [Croneis 1930, Foti 1974]. The Keys et al. name for this subsection (Boston Hills) was changed as detailed in the description of the Upper Boston Mountains. Compared with earlier Arkansas maps, this is a new subdivision of the Boston Mountain subdivision (Croneis, 1930; Foti, 1974).

231G Arkansas Valley Section.--231 Ga - Eastern Arkansas Valley - Occurs only in Arkansas (603,047 ha). Plains with hills, 90-150 m in elevation, underlain by Pennsylvanian sandstone and shale with sandy residuum are covered with pine-oak and pine woodlands and forests. Northern and eastern boundaries were modified in detail to better match topographic and geologic boundaries, respectively. The southern boundary was redefined to match the traditional physiographic boundary, Cadron Ridge (Croneis, 1930; Foti, 1974). The southwestern boundary was redefined to place all Arkansas River bottomlands within the Western Arkansas Valley subsection; topographic and geologic boundaries contributed to the subsection boundary. The Keys et al. name was changed to eliminate "and Ridges" since the redefined southern boundary eliminated the most prominent structural ridges from the subsection (this was one reason for redefining that boundary). Compared with earlier Arkansas maps, this is a new subdivision of the Arkansas Valley subdivision (Croneis, 1930; Foti, 1974). It has the least distinct boundaries within the section and is the subsection of the Arkansas Valley least influenced by the Arkansas River (which leaves this portion of

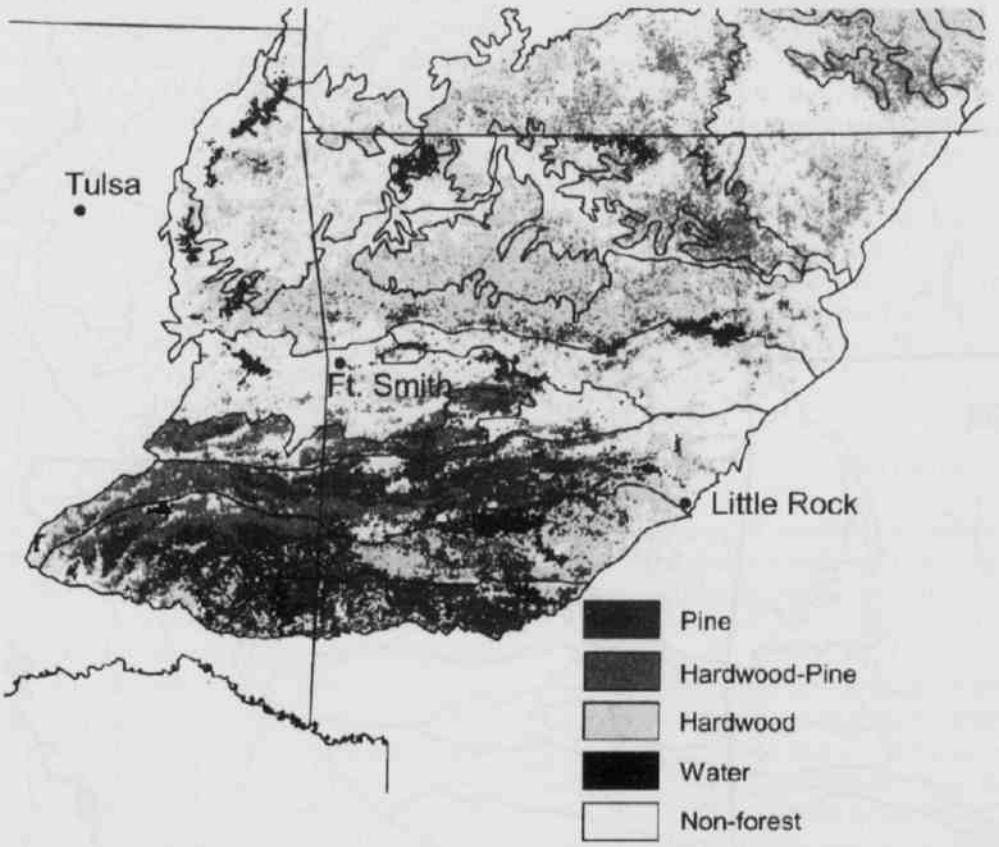

Fig. 5. Vegetation of the sections and subsections of the Interior Highlands.

the Arkansas Valley to cross the easternmost Ouachita Mountains). Without the influence of the Arkansas River, the Western Arkansas Valley would be more like this subsection and would better fit the early judgement that it was a subdivision of the Ouachita Mountain Province (Croneis, 1930). For this reason the equivalent natural division was termed the "Arkansas River Valley" by Foti (1976). However, all other authors have eliminated the word "River" from the name, and that nomenclature is followed here. Compared with earlier Arkansas maps, this is a new subdivision of the Arkansas Valley (Croneis, 1930; Foti, 1974).

231 Gb - Western Arkansas Valley Mountains - Occurs in Oklahoma (200,172 ha) and Arkansas (175,428). Low mountains and ridges with sometimes wide valleys 225-850 m in elevation underlain by Pennsylvanian sandstone and shale with sandy residuum and covered with pine-oak and oak woodlands and forests and prairies. The eastern, northern and western boundaries as delineated on the Keys map were changed somewhat based on topography to better include the mountains and exclude plains that were continuations of those in the Western Arkansas Valley. The southern boundary was changed to follow the northern boundary of the physiographic Ouachita Mountains (Croneis, 1930; Foti, 1974); the line was drawn using topography. The Keys et al. name (Mount Magazine) was changed to reflect the importance of other mountains within this subsection. Compared with earlier Arkansas maps, this is a new subdivision of the Arkansas Valley (Croneis, 1930; Foti, 1974).

231Gc - Western Arkansas Valley - Occurs in Oklahoma (335,520 ha) and Arkansas (548,332 ha). Plains, low hills and ridges, 90-300 m in elevation, underlain by Pennsylvanian sandstone and shale with sandy and clayey residuum along with Holocene sandy alluvium are covered with pine-oak and oak woodlands and forests, substantial bottomland forests, and prairies. One major low mountain, Petit Jean Mountain, was included within this section because it was disjunct from the Western Arkansas Valley Mountains, in which it would otherwise have been included. The Keys map northern, eastern and southern boundaries were refined based on topography and geology to place all of the Arkansas River alluvial plains, the most extensive alluvial plains of its major tributaries, and almost all of the Pennsylvanian erosional plains within this subsection. A

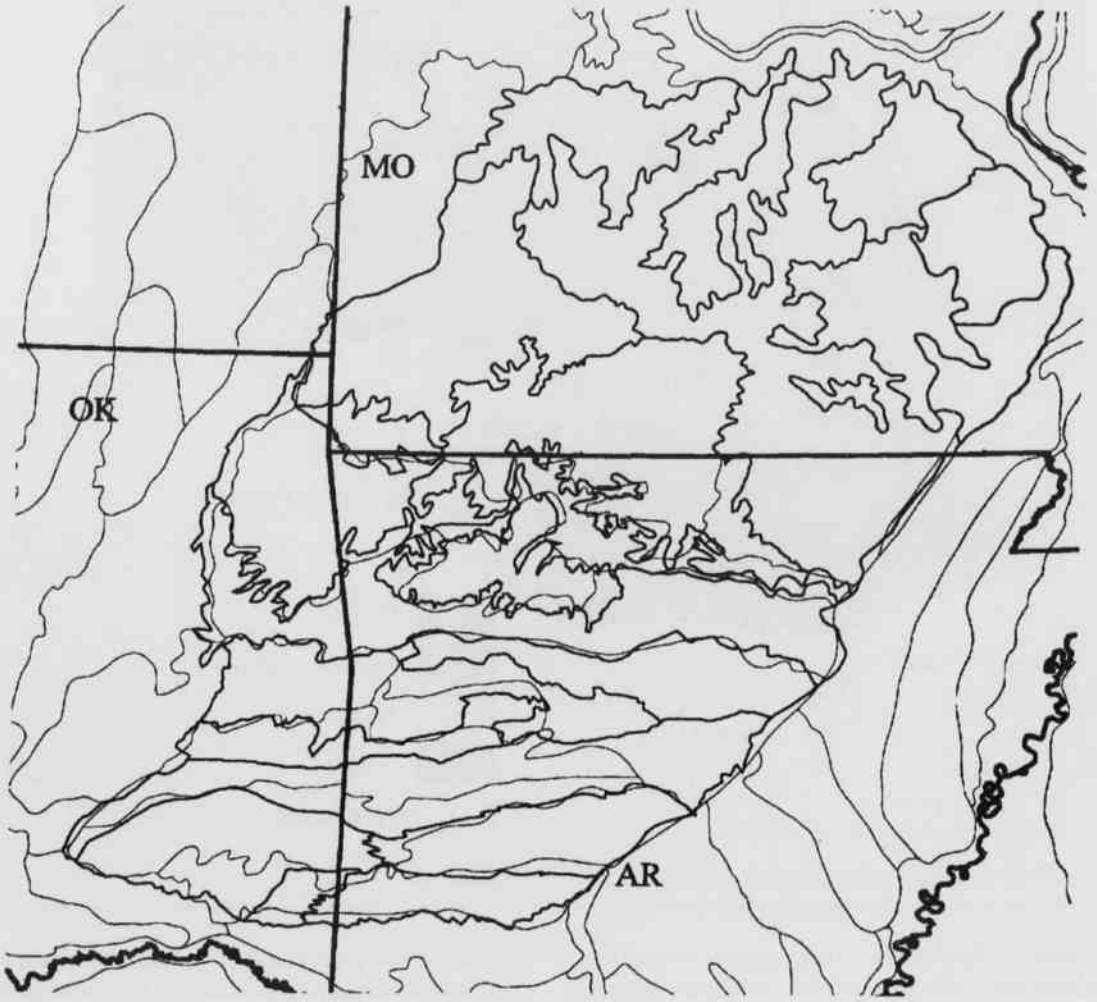

Fig. 6. Differences between new map and Keys et al. (1995). New map boundaries shown darker.

substantial area Keys et al. included that extended up the Canadian River at the western end of this subsection was eliminated on the basis of geology, topography and the definition of the Arkansas Valley as a synclinorium lying between the Ouachita Mountains and the uplifted plateaus of the Ozark Mountains (Croneis, 1930). Compared with earlier Arkansas maps, this is a new subdivision of the Arkansas Valley (Croneis, 1930; Foti, 1974).

M231A Ouachita Mountains Section.--M231Aa - Fourche Mountains - Occurs in Oklahoma (300,715 ha) and Arkansas (869,2 ha). These are open low mountain ridges, often with wide valleys, 230-850 m in elevation. Ridges are underlain by Pennsylvanian and Mississippian sandstone and shale and sandy residuum in valleys and covered with pine-oak and oak woodlands and forests. The northern boundary was modified from Keys et al. to coincide with the physiographic boundary based on topography (Croneis, 1930; Foti, 1974). The eastern portion of the southern boundary was modified to match the boundary with Mississippian Arkansas Novaculite, and further west to include the long narrow ridges of Pennsylvanian Jackfork Sandstone. Compared with earlier Arkansas maps (Croneis, 1930; Foti, 1974), this is an existing subdivision of the Ouachita Mountains but with slight reduction in area at the extreme southwestern end, now assigned to the Western Ouachita Mountains Subsection.

M231Ab - Western Ouachita Mountains - Occurs in Oklahoma (656,840 ha) and Arkansas (44,211 ha). Open high hills and low mountains often with wide valleys, 230-760 m in elevation, are underlain by Mississippian sand-

stone and shale with clayey colluvium and covered with pine-oak and oak woodlands and forests, along with prairies. Keys et al. boundaries were modified by excluding Arkansas Novaculite of the Central Ouachita Mountains from this subsection. The word "Central" was eliminated from the Keys et al. name (West Central Ouachita Mountains) because a substantial part of the subsection lies along the southern boundary of the Ouachita Mountains Section. Compared with earlier Arkansas maps (Croneis, 1930; Foti, 1974), this is a newly-mapped subdivision but only affects a small part of Arkansas.

M231Ac - Central Ouachita Mountains - Occurs in Oklahoma (98,748 ha) and Arkansas (566,689 ha). Open high hills and low mountains often with wide valleys, 230-760 m in elevation, are underlain by Mississippian sandstone and shale with clayey colluvium, covered with pine-oak and oak woodlands and forests. Keys map boundaries were modified by encompassing Arkansas Novaculite outcrops; a large disjunct area with consistent characteristics is newly delineated. The Keys et al. name was changed by dropping the "East", which was no longer needed because of the name change to the Western Ouachita Mountains. Compared with earlier Arkansas maps (Croneis, 1930; Foti, 1974), this is an existing subdivision of the Ouachita Mountains, but with an additional disjunct area added that affects only a very small part of Arkansas.

M231Ad - Athens Piedmont Plateau - Occurs in Oklahoma (22,883 ha) and Arkansas (338,961 ha). Open high hills, 150-300 m in elevation, underlain by Mississippian (with small amounts of Pennsylvanian) sandstone and shale with sandy and clay-loam colluvium are covered with pine-oak and pine woodlands and forests. The Keys map boundary was refined using the southern limit of Arkansas Novaculite for north and west boundaries; Tertiary and Cretaceous deposits define the south and east boundaries. Compared with earlier Arkansas maps (Croneis, 1930; Foti, 1974), this is an existing subdivision of the Ouachita Mountains.

Although the concepts for these sections and subsections, along with their boundaries, were based entirely on physical features (e.g., geology, topography), relationships to land cover were explored using a vegetation map of the Interior Highlands created for the OOHA Assessment (Southern Forest Experiment Station Forest Inventory and Analysis, 1992). This map was created using Advanced Very High Resolution Radiometer (AVHRR) data and, for our analysis, section/subsection boundaries were overlaid on it, allowing us to characterize the vegetation of each section/subsection (Fig. 5). A detailed analysis is presented in the OOHA Assessment (in preparation), but in summary it can be seen that the Boston Mountains and Ouachita Mountains sections have greater forest cover than the other two sections. In general the Boston Mountains Section is covered with hardwood forest whereas the Ouachitas are covered with pine and hardwood-pine forest. However the Central Ouachita Mountains Subsection has extensive coverage of hardwood and the extreme eastern Fourche Mountains Subsection has little pine and hardwood-pine, with extensive cleared lands and some hardwood forest. Even though the bulk of the Arkansas Valley Section is cleared, the Western Arkansas Valley Mountains Subsection is heavily forested, primarily with pine-hardwood. Similarly, most of the forest of the Ozark Highlands Section in Arkansas is concentrated within the White River Hills Subsection, where pine-hardwood and hardwood forests are common. In general, areas of higher relief are more heavily forested.

Discussion

This map of sections and subsections of the Interior Highlands of Arkansas and Oklahoma is the first such delineation in Oklahoma and provides significant advancements to the earlier maps by Croneis (1930) and Foti (1974) in Arkansas:

1) Boundaries are defined and mapped consistently across the three states sharing the Highlands;

2) Boundaries based on topography are much more accurate than before because of the use of 30-m DEM's;

3) Changes in section/subsection definitions that have occurred since production of the earlier maps are incorporated; and

4) This map is in digital form and freely available over the Worldwide Web.

Although production of the new map involved many changes to the Keys et al. (1995) map (Fig. 6), few changes in the list of sections and subsections were made; rather the emphasis was on employing clearly-stated boundary definitions that in most cases were first articulated by Croneis (1930), and then using appropriate digital base maps to create an accurate final product.

Similarly, the new map involves many changes to the Croneis (1930) and Foti (1974) maps. However, in most cases, subsection boundaries were added, not changed. In most cases, such as the White River Hills and Central Plateau that nest within the Salem Plateau of Croneis (1930), the Upper and Lower Boston Mountains subsections that nest within the Boston Mountain subdivision of Foti (1974), or the three new subsections within the Arkansas Valley, the new map simply adds detail to the older maps. It is still correct to refer to the Ozark Mountains as a combination of the Ozark Highlands and Boston Mountains sections or to refer to the Salem Plateau subdivision if the object of interest is not limited to one of the smaller subsections.

Examining subsections that extend from Arkansas into adjacent states adds valuable insight into their appropriate boundaries in Arkansas. The Elk River Hills and the dis-

junct portion of the Central Ouachita Mountains barely reach Arkansas, yet they are considered important regions in the other states. Recognition of the White River Hills, which are very extensive in Missouri, adds insight into the landscape diversity of the Salem Plateau in Arkansas as well.

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Speed Cut-off Point for Antiforce Waves

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Abstract

A one-dimensional, three-component, fluid model has been employed to investigate the existence of a speed cut-off point for antiforce breakdown waves. The term antiforce wave is used to identify breakdown waves for which the electric field force on electrons is in the opposite direction of wave propagation. The electron fluid-dynamical equations for antiforce waves are different from those of proforce waves. This presentation will address the difference in the set of equations for proforce and antiforce waves and the method of integration of the set of equations through the dynamical transition region for antiforce waves. Also, for antiforce waves, the existence and approximate value of a speed cut-off point will be discussed.

Introduction

The basic set of equations in the fluid model consists of the equations of conservation of mass, momentum, and energy, coupled with Poisson's equation. The three equations of conservation of mass, momentum, and energy are in Eulerian form and were adopted by Fowler (1964). Also, the wave is considered to be a shock front driven by the electron gas pressure. The shock front is followed by a dynamical transition region in which a neutral cold gas entering from the front is turned into a partially ionized hot gas.

For antiforce waves, the net electric field (applied plus space charge field) is in the direection of wave propagation. Therefore, the electric field force on electrons is in the opposite direction of wave propagation. However, the electron temperature and therefore fluid pressure are assumed to be large enough to provide the driving foree. The problem is assumed to be one-dimensional and time independent with the wave propagating along the *x*-axis. In the wave frame, the frame whose origin is located at the shock front, the electrons, ions, and neutral particle velocities and number densities are time independent.

Model and Theory

Consider the breakdown wave as an infinite plane wave traveling in the positive x direction with a speed V. Due to the absence of observed Doppler shift, in the wave frame, the frame which the wave front is considered to be stationary, the ions and neutral particles will have a velocity of – V, and the wave will extend from 0 to – ∞. The shock front at x = 0 divides the neutral particles in front of the wave from the three component gas (electrons, ions, and neutral particles) behind the wave.

In gas electrical discharge, the wave front is followed by a dynamical transition region. In this region the net electric field (applied plus space charge field), starting from its value E_0 at the wave front, falls to zero at the trailing edge of this region. This region, which is somewhat thicker than a Debye length, is referred to as the sheath region. At the end of the sheath region the electrons come to rest relative to ions and neutral partieles. These physical conditions will be the guiding tool in solving the set of electron fluid-dynamical equations. Since 1964, Fowler's (1964) set of electron fluid dynamical equations has been improved. The set of equations which have proven to be suceessfull in the case of proforce waves was completed by Fowler et al. (1984). Their set of equations include equations of conservation of mass, momentum, and energy. Coupled with Poisson's equation and in one dimension, they are, respectively

$$\frac{d(nv)}{dx} = \beta n, \tag{1}$$

$$\frac{d}{dx}\left\{ nmv(v - V) + nkT_e \right\} = -enE - Kmn(v - V), \tag{2}$$

$$\frac{d}{dx}\left\{ nmv(v - V)^2 + nkT_e(5v - 2V) + 2e\phi nv + \epsilon_0 VE^2 - \frac{5nk^2 T_e}{mk}\frac{dT_e}{dx} \right\} = -3\left(\frac{m}{M}\right) nkKT_e - nmK\left(\frac{m}{M}\right)(v - V)^2, \tag{3}$$

$$\frac{dE}{dx} = \frac{en}{\epsilon_0}\left(\frac{v}{V} - 1\right). \tag{4}$$

The symbols n, v, m, e, and T_e represent electron number density, velocity, mass, charge, and temperature inside the sheath, and k, K, β, ϕ, V, M, E_0, x are Boltzman constant, elastic collision frequency, ionization frequency, ionization potential, wave velocity, neutral particle mass, electric field at the wave front, and position inside the sheath, respectively.

For antiforce waves, Sanmann and Fowler (1975) considered the wave to be charaeterized by a weak discontinuity at its front. That is, the electron temperature and number density derivatives were considered to change discontinuously; however, the variables themselves changed continuously. For examplee, his conditions on electron number density, n, at the wave front were n=0 and $\frac{dn}{dx} \neq 0$. Application of Sanmann's approximate method of solutions and initial conditions reflecting a weak discontinuity to the completed set of electron fluid dynamical equations did not bear fruit; therefore, we had to consider an alternate approach.

In our attempts to solve the set of equations, assuming a strong discontinuity (a shock front), has proven to be successful. That is, at the wave front the variables such as electron temperature and number density change discontinuously. Sanmann and Fowler (1975) used variables suggested by Shelton and Fowler (1968) to reduce the set of equations to nondimensional form. However, these variables lead to a contradiction in sign for the variables. Therefore, we will choose a slightly different set of variables, and they are

$$\eta = \frac{E}{E_0}, \quad \xi = -\frac{eE_0}{mV^2}x, \quad \psi = \frac{v}{V}, \quad \theta = \frac{kT_e}{2e\phi}, \quad \nu = \frac{2e\phi}{\epsilon_0 E_0^2}n,$$

$$\omega = \frac{2m}{M}, \quad \mu = \frac{\beta}{K}, \quad \alpha = \frac{2e\phi}{mV^2}, \quad \kappa = -\frac{mVK}{eE_0}$$

In the above equations, ν, ψ, θ, μ, κ, η, and ξ are the dimensionless electron concentration, electron velocity, electron temperatue, ionization rate, elastic collision frequency, electric field, and position inside the sheath, respectively. All the above nondimensional quantities, including κ, are intrinsically positive. Introducing the above dimensionless variables in the equations 1-4 results in

$$\frac{d(\nu\psi)}{d\xi} = \kappa\mu\nu, \tag{5}$$

$$\frac{d}{d\xi}\left\{\nu\psi(\psi-1)+\alpha\nu\theta\right\} = \nu\eta - \kappa\nu(\psi-1), \tag{6}$$

$$\frac{d}{d\xi}\left\{\nu\psi(\psi-1)^2+\alpha\nu\theta(5\psi-2)+\alpha\nu\psi+\alpha\eta^2-\frac{5\alpha^2\nu\theta}{\kappa}\frac{d\theta}{d\xi}\right\} = -\omega\kappa\nu\left\{3\alpha\theta+(\psi-1)^2\right\}, \tag{7}$$

$$\frac{d\eta}{d\xi} = \frac{\mu}{\alpha}(1-\psi). \tag{8}$$

Solution of the Equations

At the shock front, the electron velocity, v, is not as high as the wave velocity, V. Therefore, the value of the nondimensional electron velocity, v, will be less than one. All varaibles are intrinsically positive; therefore, at the wave front Poisson's equation will yield a positive electric field derivative ($\frac{d\eta}{d\xi} > 0$). This indicates that, traversing the sheath, at first the nondimensional electric field value will increase from its initial value of 1. However, gradually the electrons reach speeds larger than those of ions and neutral particles. This results in ψ values larger than one, and therefore, a negative value of electric field derivative ($\frac{d\eta}{d\xi} < 0$). Thus, the electric field value starts decreasing. Since a contained volume of plasma cannot support an electric field, as one approaches the trailing edge of the sheath the electric field value must approach zero ($\eta \rightarrow 0$). Approaching the end of the sheath, due to collisions with heavy particles, the electrons slow down to speeds equal to those of heavy particles. The dimensionless electron velocity value, therefore, must approach unity at the end of the sheath ($\psi \rightarrow 1$).

Integrating the electron fluid dynamical equations through the sheath region, the physical conditions at the end of the sheath, referred to in the above paragraph, will become the guiding tool. For given values of α and κ, a combination of initial electron number density, υ_1, and initial electron velocity, ψ_1, are selected. Then, for such a combination, the equations are numerically integrated and variations of the variables through the sheath region are observed. κ is called the wave constant and determines the relation between the laboratory wave speed and the initial value of the electric field. Changes in the value of κ are utilized for dramatic impact in the process of numerical integration. Additionally, the values of υ_1 and ψ_1 are altered to achieve a solution by trial and error.

Through the sheath region, the electron fluid dynamical equations have successfully been integrated for six values of α (0.01, 0.05, 0.1, 0.25, 1, 2). $\alpha = 0.01$ represents a fast wave speed ($V \approx 3 \times 10^7$ m/s) and $\alpha = 2$ represents a slow wave speed ($V \approx 2 \times 10^6$ m/s). Figure 1 is a plot of the electric field, η, as a function of electron velocity, ψ, inside the sheath for all six values of α. The graphs show that for all six values of α the solutions to the electron fluid dynamical equations conform to the expected physical conditions at the end of the sheath. To achieve successful integration for different values of α, the following values of κ and initial electron velocity and electron density had to be utilized:

$\alpha = 0.01$, $\kappa = 1.3$, $\nu_1 = 0.886$, and $\psi_1 = 0.645$
$\alpha = 0.05$, $\kappa = 0.6$, $\nu_1 = 0.853$, and $\psi_1 = 0.801$
$\alpha = 0.1$, $\kappa = 0.477$, $\nu_1 = 0.801$, and $\psi_1 = 0.924$
$\alpha = 0.25$, $\kappa = 0.3883$, $\nu_1 = 0.985$, and $\psi_1 = 0.96$
$\alpha = 1$, $\kappa = 0.22$, $\nu_1 = 0.9$, and $\psi_1 = 0.94$
$\alpha = 2$, $\kappa = 0.16$, $\nu_1 = 0.93094$, and $\psi_1 = 0.97$

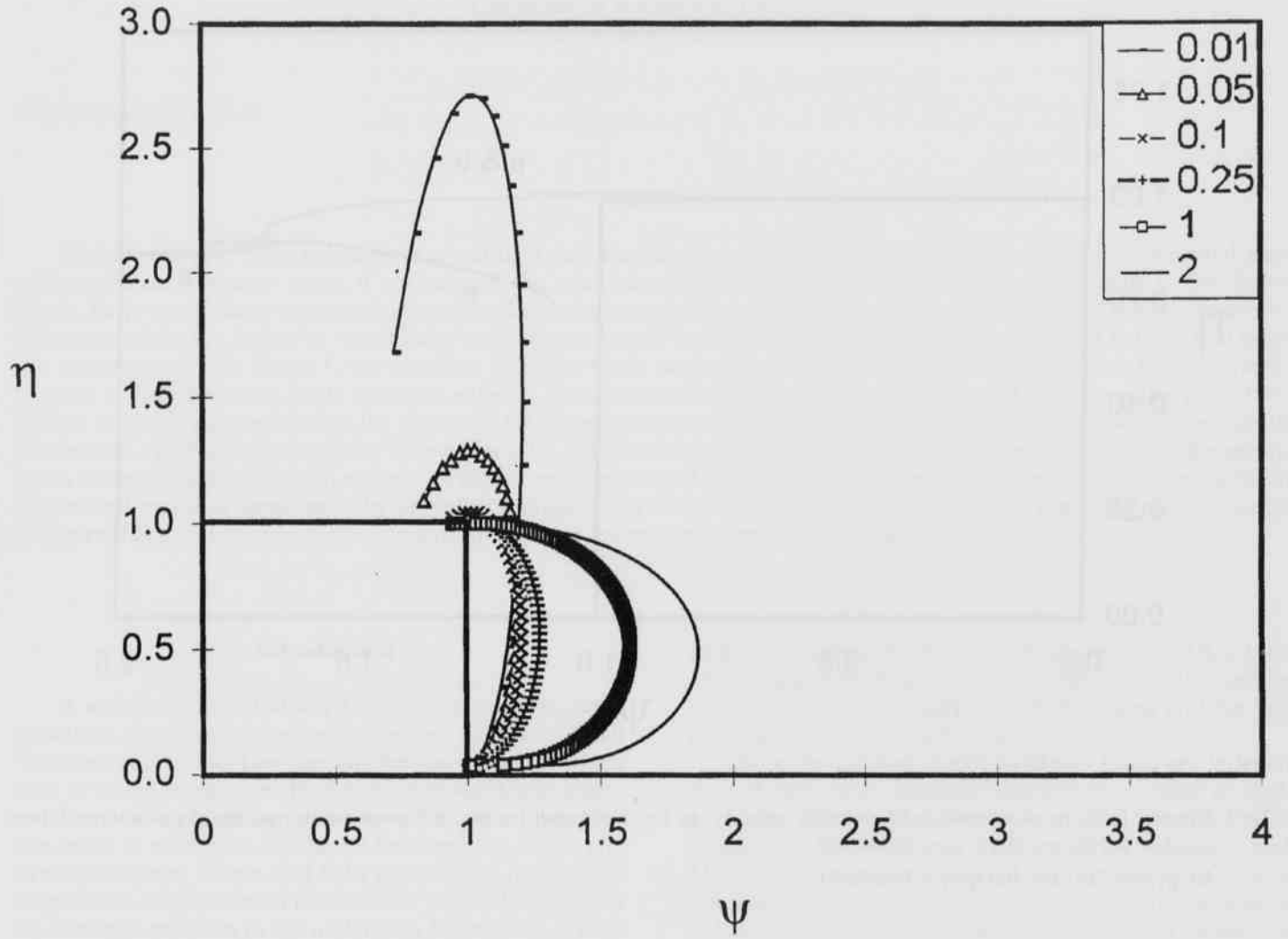

Fig. 1. Electric field, η, as a function of electron velocity, ψ, for six different values of α. α = 0.01, 0.05, 0.1, 0.25, 1, and 2.

As the value of α increases, the wave speed decreases and the numerical integration of the electron fluid dynamical equations becomes more difficult. Solution for α = 2 required long hours of computer work and analysis. A great deal of time was spent trying to achieve solution for α = 4; however, there seems to be no solution for α = 4. Therefore, there seems to be a cut-off point for values of α which allow successful integration of the set of equations (η → 0, ψ → 1). That is, there seems to be a cut-off point for wave speeds. Figure 2 shows graphs of electric field, η, as a function of electron velocity, ψ, for two sets of variables. A slight variation of υ_1 results in two different paths, neither is an acceptable solution.

Conclusions

For antiforce waves and for six different values of wave speeds, the electron fluid dynamical equations have successfully been integrated. The integration of the equations become more difficult as the breakdown wave speed decreases. There seems to be a cut-off point in the value of α beyond which successful integration of the equations is not possible. That is, there seems to be a cut-off point for wave speeds.

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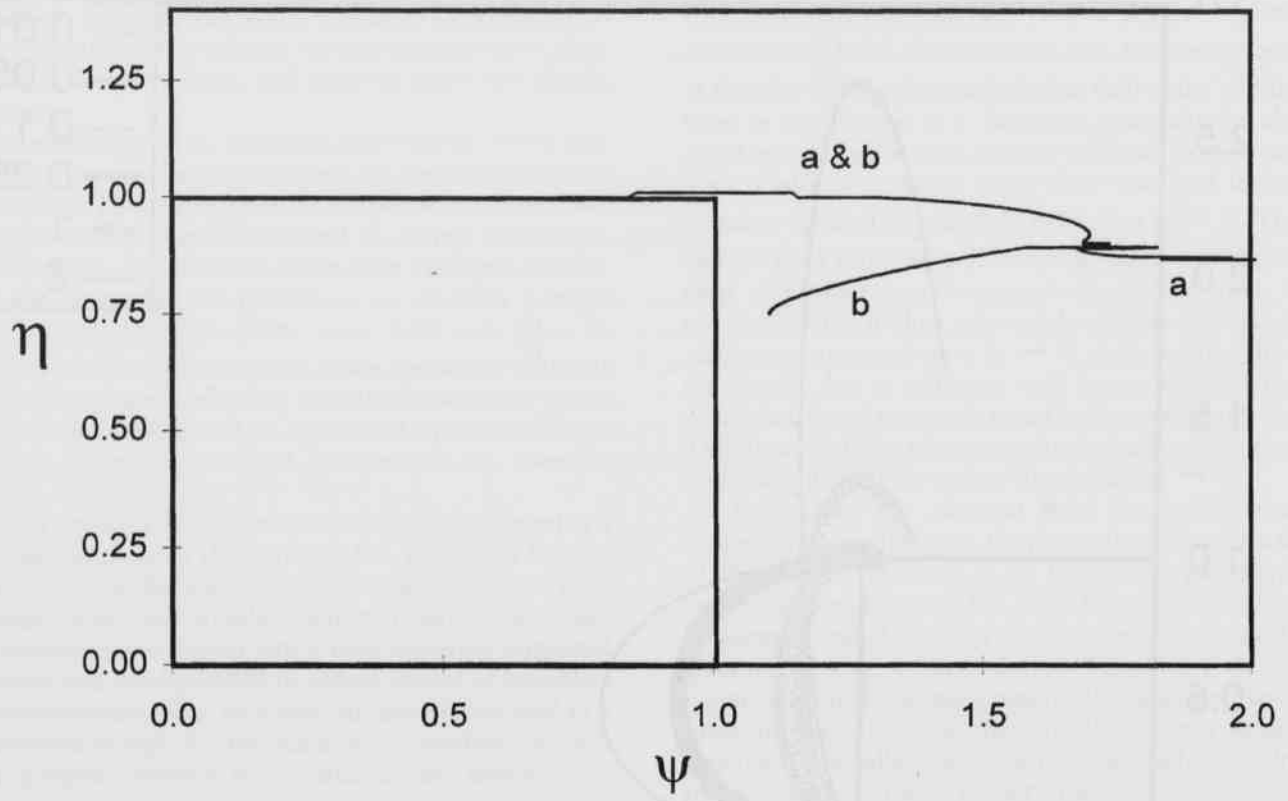

Fig. 2. Electric field, η, as a function of electron velocity, ψ, for $\alpha = 4$ and for two different combinations of parameter values.
a) $\psi_1 = 0.710$, $\kappa = 0.33$, $\nu_1 = 0.398502$
b) $\psi_1 = 0.710$, $\kappa = 0.33$, $\nu_1 = 0.398501$

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Applying Binomial Statistics to Weighted Monte Carlo

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Abstract

Weighted Monte Carlo calculations requiring a uniform sampling of the problem-space can suffer from diminished statistical significance because many, if not most, of the randomly-chosen sampling points contribute only slightly to the desired result. Their contribution is reduced in size due the variable-size of the weighting terms. In contrast, none of the randomly-chosen points which are *favored* by variablesize weighting terms will have their statistical significance enhanced beyond that of just *one random point* in the Monte Carlo sampling. A Monte Carlo analysis was used in earlier work to verify both Gauss' Law and Newton's Shell Theorem. Both examples suffered from statistical difficulties since each Monte Carlo sampling point has a weight inversely proportional to the square of the distance between source and field points. The present work analyzes the diminished significance in weighted Monte Carlo for the specific example of Newton's Shell Theorem, describing the geometry in terms of closest approach distance of the spherical mass shell to the field point. Binomial Statistics is used to remedy this diminished statistical significance by providing a prescription for increasing the value of the Monte Carlo sample size needed to assure that the chosen precision remains invariant as the mass-shell geometry is changed.

Introduction

A weighted-form of Monte Carlo is applicable to many problems in physics and engineering. Newton's Shell Theorem and Gauss' Law are two famous examples which may be tested using a weighted-form of Monte Carlo analysis. The $1/\Delta R^2$ weighting terms in each of these examples can result in numerical infinities if the sampling allows any overlap between source and field points. This problem of singularities is a numerical nuisance for Monte Carlo, not a fundamental problem in the underlying formulation. These are specious infinities because singularities rarely occur in the analytical formulations. In each example, Newton's Shell Theorem and Gauss' Law, the offending $1/\Delta R^2$ is cured analytically by cancellations, resulting, at worst, in a predicted discontinuity in the observable (Halliday and Resnick, 1988).

Either a weighted-Monte Carlo problem must be reformulated to no longer require a uniform sampling of the entire space, a programmer-intensive task–not certain to succeed, or a large number of samples must be taken to remedy the diminished statistical significance of lower-weighted samples (Mikhailov, 1992). Figure 1 develops Binomial Statistics (Boaz, 1983) to provide an analysis for weighted Monte Carlo problems which works almost everywhere, even near Monte Carlo singularities. The present binomial analysis results in a rationale and a prescription for just how large the Monte Carlo sampling-size N must be as a function of ΔR_{CA} to assure the chosen level of precision. ΔR_{CA} is the closest approach distance between the uniformly sampled (source) points on the spherical shell of mass and the field point, just above the earth's surface.

Since the random events in Monte Carlo are independent of each other, Binomial Statistics is expected to apply to Monte Carlo. The binomial success fraction "p" is hypothesized to exist and have a unique value for each Monte Carlo geometry selected. Three variables (p, N, ε) are related in Fig. 1: $p = 1/[N\varepsilon^2 + 1]$, with N the number of independent event samples and ε the fractional variance in the observable.

The longitudinal force component of Newton's Shell Theorem was the chosen observable (Halliday and Resnick, 1988). A Monte Carlo analysis was used to test the hypothesis that the binomial probability of success "p" exists and has a unique value for any particular choice of geometry. Figure 2 shows an example of Monte Carlo geometry where the uniform-mass shell is located 90% of the distance to the earth's surface.

Each set of Monte Carlo calculations was repeated 1000 times for each of 24 distinct values of the parameter N. Each set of N Monte Carlo samplings of points on the mass shell provided a value for the longitudinal force component (F) at some precision σ_F. One Thousand repeated Monte Carlo samples were used to extract an estimate of this precision σ_F from the sum of the squares of the deviations of F from its average value $\langle F \rangle$ (Bevington and Robinson, 1992). This

Binomial Statistics

$\boxed{p+q=1}$

p = probability of success, q= probability of failure.
p & q are unchanged in N repeated events. N events unrelated $\Rightarrow$ outcome probability a simple product.

n_1= # of successes $\Rightarrow p^{n_1}$; n_2= # of failures $\Rightarrow q^{n_2}$.

$\frac{N!}{n_1!n_2!}$ = *multiplicity* for $\boxed{p^{n_1}q^{n_2}}$ term, $\boxed{n_1+n_2=N}$.

$\boxed{p\frac{\partial}{\partial p}}$ & $\boxed{p\frac{\partial}{\partial p}p\frac{\partial}{\partial p}}$ provide $<n_1>$ and $<n_1^2>$ below.

$$\boxed{(p+q)^N \equiv \sum_{n_1=0}^{N} \frac{N!}{n_1!n_2!}\, p^{n_1} q^{n_2} \rightarrow 1,\ \boxed{n_1+n_2=N}}.$$

$$<n_1> \equiv \sum_{n_1=0}^{N} n_1 \frac{N!}{n_1!n_2!}\, p^{n_1}q^{n_2} \equiv p\frac{\partial}{\partial p}\sum_{n_1=0}^{N} \frac{N!}{n_1!n_2!}\, p^{n_1}q^{n_2}$$

$$<n_1^2> \equiv \sum_{n_1=0}^{N} n_1^2 \frac{N!}{n_1!n_2!}\, p^{n_1}q^{n_2} \equiv p\frac{\partial}{\partial p}p\frac{\partial}{\partial p}\sum_{n_1=0}^{N} \frac{N!}{n_1!n_2!}\, p^{n_1}q^{n_2}$$

$$p\frac{\partial}{\partial p}(p+q)^N \equiv Np(p+q)^{N-1},\ (p+q=1) \Rightarrow \boxed{<n_1> = Np}$$

$$\left[p\frac{\partial}{\partial p}p\frac{\partial}{\partial p}\right] \equiv \left[p\frac{\partial}{\partial p} + p^2\frac{\partial^2}{\partial p^2}\right],\left[p\frac{\partial}{\partial p} + p^2\frac{\partial^2}{\partial p^2}\right](p+q)^N \equiv$$

$$<n_1^2> = Np(p+q)^{N-1} + N(N-1)p^2(p+q)^{N-2},\ (p+q=1) \Rightarrow$$

$$\boxed{<n_1^2> = Np + N(N-1)p^2} \cdot \boxed{\text{Fractional variance (in the observable)}} \equiv \varepsilon \equiv \frac{\sigma_1}{<n_1>} \equiv$$

$$\frac{\sqrt{<n_1^2> - <n_1>^2}}{<n_1>} = \frac{\sqrt{Np + N(N-1)p^2 - N^2p^2}}{Np} = \frac{\sqrt{Np - Np^2}}{Np}$$

$$\frac{\sigma_1}{<n_1>} \equiv \boxed{\varepsilon = \frac{\sqrt{(1-p)/p}}{\sqrt{N}}} \Rightarrow \boxed{p = \frac{1}{N\varepsilon^2 + 1}} \text{ and } \boxed{N = \frac{1-p}{p\varepsilon^2}}.$$

Fig 1. Binomial Statistics is outlined for an analysis of Monte Carlo, providing three (equivalent) relationships between three variables: ε, P and N.

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estimate of σ_F is used to approximate the fractional variance in the observable, $\varepsilon = \sigma_F/\langle F \rangle$; ε is used with the parameter N to calculate a value for the binomial probability of success: $p = 1/[N\varepsilon^2 + 1]$. It is interesting and obvious that $N\varepsilon^2$ must form an invariant product for any particular (chosen) geometry or the binomial success fraction "p" would not exhibit a constant (unique) value, independent of N. for the geometry selected in Fig. 2. If the value of "p" did not exhibit a unique value (i.e., if "p" were not independent of N) then Binomial Statistics would not provide a useful analysis of weighted Monte Carlo problems.

Using this two-level Monte Carlo analysis, a value was extracted for "p" for each value of the parameter N and displayed in Fig. 2. The constancy of "p" over a dynamic range in N of 1000:1 empirically verifies it to be unique for the geometry specified in Fig. 2. A value for "p" was calculated for each of the 24 different values between 1,000 and 1,000,000 chosen for N using the numerically extracted (fractional variance) ε calculated for each value of the parameter N. The resulting "p" is seen to have a constant value independent of N. This result means that $N\varepsilon^2$ does indeed form an invariant product for the chosen geometry (see Fig. 2) or the value of "p" would not be constant and independent of N.

Materials and Methods

The present work examines the effort to verify Sir Isaac Newton's Shell Theorem using weighted Monte Carlo. One version of Newton's Shell Theorem states (1) For any field point *outside* a uniform spherical mass shell, the shell acts as though all its mass were concentrated at its symmetry center. [Only longitudinal forces survive as transverse forces vanish by symmetry.] (2) For any field point located *inside* a uniform spherical mass shell, the shell acts as though its mass were zero (i.e., the mass shell provides no net gravitational force on an enclosed field point).

Binomial Statistics was chosen as the vehicle for studying the onset of diminished statistical significance in this weighted Monte Carlo problem. Earlier work (McCloskey and Braithwaite, 1995) used Monte Carlo to verify both Gauss' Law and Newton's Shell Theorem. Both these efforts are examples of the use of weighted Monte Carlo calculations since each sampling point is weighted inversely by the square of the distance between source and field points.

Binomial Statistics is relevant to this class of weighted Monte Carlo problems since for each geometrical situation there is a unique value for the sampling probability (interpreted as the binomial probability of success). As required for binomial statistics to be valid, each sampling probability is independent of all prior and future samplings. Further, this probability of success is $p \rightarrow 1$ when all events are weighted equally.

In verifying Newton's Shell Theorem using Monte Carlo, $p \approx 1$ when the distance between source and field points is much larger than the extended size of the source-distributions of mass (as in the earth-moon system). [The Monte Carlo points plotted in Fig. 5 show $p \approx 1$ for $R \approx 0$ (since the distance of closest approach is $\Delta R_{ca} \approx 1$); all Monte Carlo point events on the spherical mass shell are weighted approximately equally.] Newton developed his Shell Theorem to determine the force of gravity at the earth's surface by viewing the mass of the earth as distributed in uniform, concentric spherical shells arranged much like the layers of an onion (Halliday and Resnick, 1988).

When the closest-approach distance is small compared to size-distribution of source-masses, only the closest points on the mass shell contribute significantly to the Monte Carlo sampling of force components at the (nearby) field point. The farther-away points are relegated, progressively, to statistical insignificance by the $(\Delta R)^{-2}$ weighting of the Monte Carlo samples. The size of binomial probability of success "p" is expected to fall monotonically from unity for each mass-shell geometry, as the distance of closest approach ΔR_{ca} progressively decreases.

Figure 2 shows a spherical mass shell for $\Delta R_{ca} = 0.1$ ($R = 0.9$ and the earth's radius = 1). Mass points near the field point on the earth's surface are favored with a weighting of $\approx 1/0.1^2 = 100$ in contrast to mass points on the far side of the shell which are disfavored with a weighting of $\approx 1/2^2 = 1/4$. This means these "near points" are weighted by about a factor of ≈ 400 over the "far points."

For $\Delta R_{ca} = 0.01$ (and $R = 0.99$) "near points" are favored by $\approx 40{,}000$ over the "far points." As ΔR_{ca} approaches zero, the probability of success for any particular sample "p" also approaches zero. The radius of the contributing part of the shell (associated with "near points") scales with ΔR_{ca}, so the area of the contributing part of the shell (associated with "near points") scales as $(\Delta R_{ca})^2$, and asymptotically, one might expect $p \propto (\Delta R_{ca})^2$. It is well known that a power law graphs as a straight line on a log-log plot with the slope of the graph being the "power." The asymptotic variation of "p" is shown in the final analytical calculation of Fig. 4 as well as in the log-log graph of Fig. 5. Asymptotically both analytical and graphical presentations show $p \propto (\Delta R_{ca})^2$.

Results and Discussion

Monte Carlo was used (above) to verify the hypothesis that the binomial success probability "p" exists and has a unique value for $\Delta R_{ca} = 0.1$ (one particular geometry). The fractional variance ε in the observable was determined for each value of the parameter N, and "p" was calculated using the formula: $p = 1/(N\varepsilon^2 + 1)$. Results of these calculations

The Binomial Statistics probability of success, p, is hypothesized to exist with a unique value at each ΔR_{ca}.

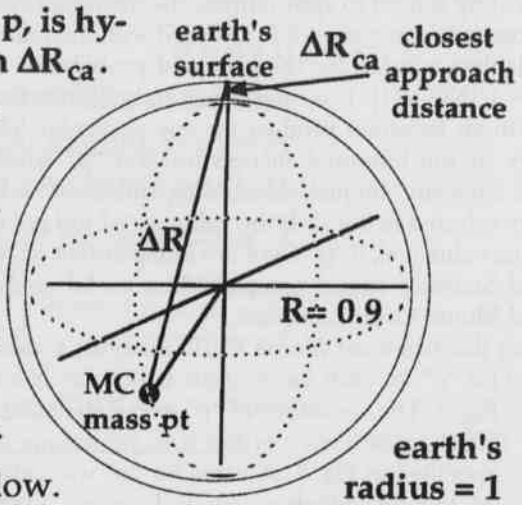
$$p = \frac{1}{N\varepsilon^2 + 1}$$

N is # of MC samples, ε is the fractional variance in the observable (z-comp. of Force).

MC averages force components by sampling mass points on spherical mass shell (right).

For each independent variable N, 1000 sets of MC averagings of force component, and the variance is extracted using standard methods.

p, extracted for each value of N, is plotted below.



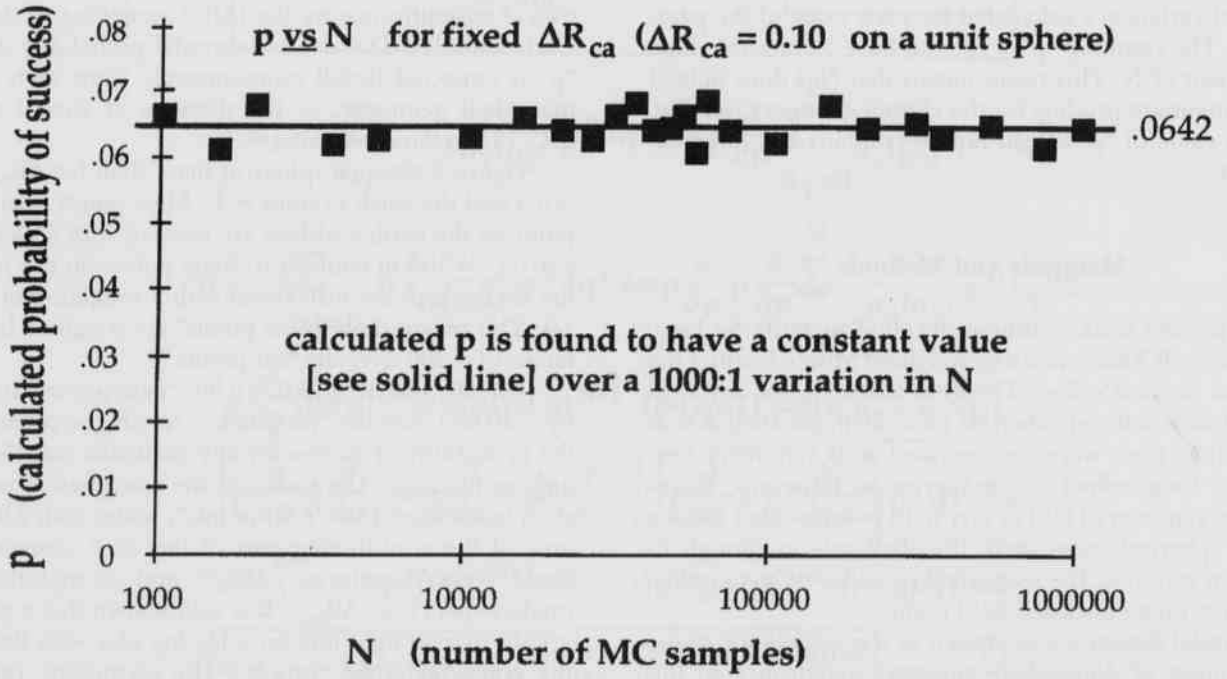


Fig. 2. p is extracted using two-level Monte Carlo analysis: N is chosen as an independent parameter in each set, with ε determined by standard methods from 1000 sets of averagings.

are shown in Fig. 2. "p" was seen to have a unique value for a 1000:1 variation in the parameter N. Flutter in these Monte Carlo points (plotted as squares) is consistent with a fractional uncertainty of ≈3%, about the size of the squares. (A unique value for "p" for the chosen geometry occurs only if $N\varepsilon^2 \approx$ constant.)

Figure 3 begins the next step, which is to calculate the fractional variance in the transverse force component analytically, to calculate a unique "p" as a function of the closest approach distance ΔR_{ca}. ΔR_{ca} is sufficient to specify the geometry of each mass shell in its relationship to the field point (just above the surface of the earth). Figure 3 provides a diagram and outlines a method for calculating the fractional variance in the observable, by analytically averaging

Using Binomial Statistics in an Analysis of Newton's Shell Theorem for Monte Carlo

The longitudinal component of the Force is:

$$F_{sz} = \frac{\cos\phi}{s^2}$$

Find $\langle F_{sz} \rangle$ by averaging this force component over the spherical shell (below).

Then find $\langle F_{sz}^2 \rangle$ by averaging the square of the force component over the spherical shell.

The goal is to find the fractional variance in this observable to obtain N needed for MC.

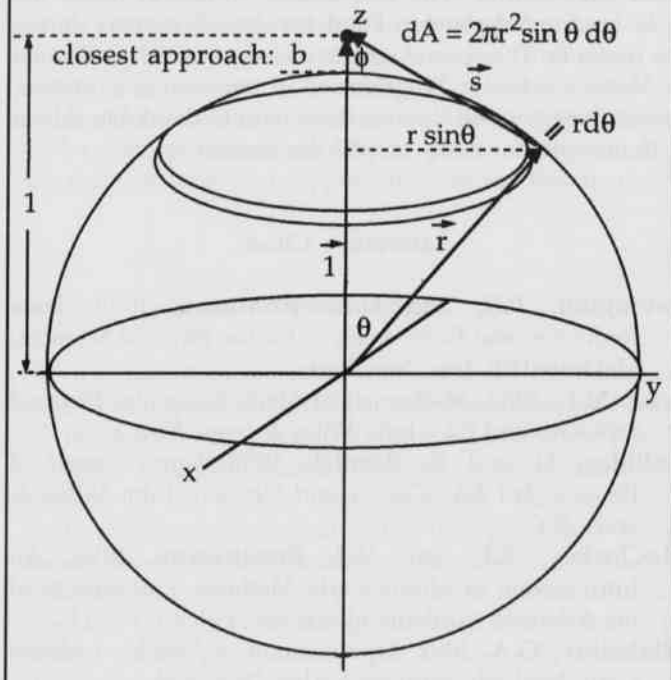


Fig. 3. The longitudinal component of the gravitational force (from a spherical shell) is selected as the observable whose fractional variance is needed in the analysis of Newton's Shell Theorem to determine the Monte Carlo sample size, N=N(p, ε), to assure the precision is unaffected by geometry.

Binomial probability of success, p, for a single MC event

Force (longitudinal component):

$$\langle F_{sz} \rangle = \frac{1}{2\pi r^2} \int_0^{\pi} \frac{\cos\phi}{s^2} 2\pi r^2 \sin\theta \, d\theta \qquad F_{sz} = \frac{\cos\phi}{s^2}$$

and $$\langle F_{sz}^2 \rangle = \frac{1}{2} \int_0^{\pi} \frac{\cos^2\phi}{s^4} \sin\theta \, d\theta$$

vectors give geometrical relations:

$$\vec{r} = \vec{1} - \vec{s} \Rightarrow r^2 = 1 + s^2 - 2s\cos\phi \Rightarrow \cos\phi = \frac{1 - r^2 + s^2}{2s}$$

$$\vec{s} = \vec{1} - \vec{r} \Rightarrow s^2 = 1 + r^2 - 2r\cos\theta$$

substitute: $$\Rightarrow s\,ds = r(-\sin\theta)\,d\theta$$

$$\langle F_{sz} \rangle = \frac{1}{2} \int_0^{\pi} \frac{\cos\phi}{s^2} \sin\theta \, d\theta = \frac{1}{2r} \int_{1-r}^{1+r} \frac{1}{s^2} \frac{1 - r^2 + s^2}{2s} ds =$$

$$\frac{1}{4r} \int_{1-r}^{1+r} \frac{1 - r^2 + s^2}{s^2} ds = \frac{1}{4r} \left[-\frac{(1-r)(1+r)}{(1+r)} + \frac{(1+r)(1+r)}{(1+r)} + 1 + r - (1-r) \right]$$

$$\langle F_{sz} \rangle = 1 = \frac{4r}{4r} \cdot \qquad \langle F_{sz}^2 \rangle = \frac{1}{2r} \int_{1-r}^{1+r} \left[\frac{1}{s^2} \frac{1 - r^2 + s^2}{2s} \right]^2 s\,ds =$$

$$\frac{1}{8r} \int_{1-r}^{1+r} \left[\frac{(1-r)^2(1+r)^2}{s^6} + 2\frac{(1-r)(1+r)}{s^4} + \frac{1}{s^2} \right] s\,ds = \frac{1}{8r} \left[\frac{(1-r)^2(1+r)^2}{4s^4} - 2\frac{(1-r)(1+r)}{2s^2} + \ln(s) \right]_{1-r}^{1+r}$$

$$= \frac{1}{8r} \left[\frac{(1-r)^2(1+r)^2}{4(1+r)^2} + \frac{(1-r)^2(1+r)^2}{4(1-r)^2} - \frac{(1-r)(1+r)}{(1+r)^2} + \frac{(1-r)(1+r)}{(1-r)^2} + \ln\left\{\frac{1+r}{1-r}\right\} \right] \cong \frac{1}{8b^2}$$

$$\langle F_{sz}^2 \rangle = \frac{1}{8r} \left[\frac{(1+r)^2}{4(1-r)^2} - \frac{(1-r)^2}{4(1+r)^2} + \frac{1+r}{1-r} - \frac{1-r}{1+r} + \ln\left\{\frac{1+r}{1-r}\right\} \right] \cong \frac{1}{8b^2}$$

closest approach: $b \equiv 1-r$, $r \equiv 1$ $1+r \equiv 2$, ε = chosen precision

$$\sigma^2(F_{sz}) = \varepsilon^2(F_{sz}) = \langle F_{sz}^2 \rangle - 1 \cong \frac{1}{8r\,b^2} - 1 \qquad N = \frac{1-p}{p\,\varepsilon^2} \cong \frac{1}{8b^2\varepsilon^2}$$

Binomial probability of success, p, for a single MC event is:

$$p = \frac{1}{\varepsilon^2(F_{sz}) + 1} = \frac{1}{\frac{1}{8r}\left[\frac{(1+r)^2}{4(1-r)^2} - \frac{(1-r)^2}{4(1+r)^2} + \frac{1+r}{1-r} - \frac{1-r}{1+r} + \ln\left\{\frac{1+r}{1-r}\right\} \right]} \cong 8b^2$$

Fig. 4. The fractional probability of success (p) for fixed geometry is calculated via Binomial Statistics from the fractional variance in the longitudinal component of the gravitational force. Approximate values of p and N are also provided.

F_{sz} and $(F_{sz})^2$ over a spherical shell of radius r.

An expression which works for almost all spherical shells of radii (i.e., $0 \le R < 1$) was calculated for the binomial probability of success "p" in Fig. 4 and plotted as a solid line in Fig. 5. The analytical calculation of Fig. 4 is seen in Fig. 5 to agree well with a collection of individual Monte Carlo calculations for "p," which are represented in Fig. 5 by squares, with each repeated Monte Carlo calculation represented by a diamond. In addition, a dotted line shows the asymptotic prediction for "p" which is seen to improve progressively for decreasing values of closest approach ($b \equiv \Delta R_{ca}$) in the range $0 < b < 0.1$.

Figure 4 outlines the calculation that provides an exact analytical prediction for the binomial probability of success "p," as well as providing approximate values for sufficiently

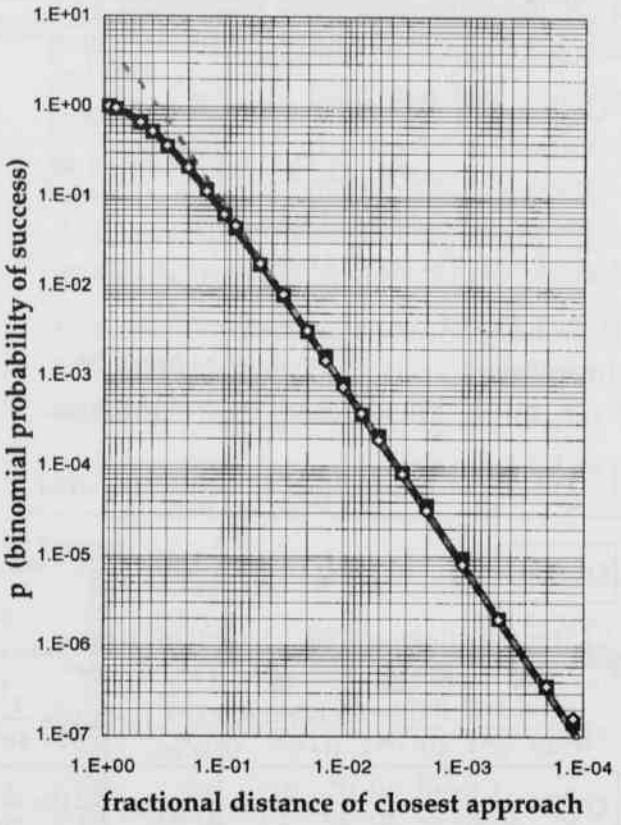


Fig. 5. The calculated probability of success (p) is plotted versus fractional distance of closest approach. Square and diamond data points are from repeated calculations. The dotted line is asymptotically correct for p as r approaches l.

small values of the closest approach (i.e., for $b \ll r \approx 1$: $p \approx 8b^2$). The dotted line in Fig. 5 shows the asymptotic prediction for "p" [$p = 8(\Delta R_{ca})^2 = 8b^2$] is an excellent approximation for $b \equiv \Delta R_{ca} < 0.05$, as the dotted graph lies exactly on top of the solid line (representing the exact prediction) to within the accuracy of the display.

Figure 5 is a log-log plot of the predictions for "p" from the exact calculation (solid), from the asymptotic calculation (dotted) and from the repeated Monte Carlo calculations (squares and diamonds). The exact and Monte Carlo predictions are seen to be in excellent agreement, with the dotted line showing the expected asymptotic variation: $p = 8(\Delta R_{ca})^2 \propto (\Delta R_{ca})^2$ for small $b \equiv \Delta R_{ca}$. In terms of the calculations of Fig. 4, only the first term in the denominator for "p" is retained to provide the asymptotic prediction. A straight-line variation on a log-log plot is the result of a power law, where the *slope* of the plot provides the value of the exponent. Note the graphical agreement in the asymptotic region, where "p" drops two orders of magnitude for every one order of magnitude decrease in the fractional distance of closest approach.

Since "p" is known it may be used to the remedy the diminished statistical significance in the Monte Carlo by providing the desired prescription for increasing the sample size (N) needed to assure that the chosen precision (ε) remains invariant as mass-shell geometry is changed. $N = (1 - p)/(p\varepsilon^2)$ is the exact prescription using values for p from Fig. 5. The asymptotic $p \approx 8b^2$ provides an asymptotic prescription for $N \approx .125/(b\varepsilon)^2$, where $b \equiv \Delta R_{ca}$.

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Quantifying Community Separation and Increase in Number of Avian Species with Corresponding Increase in Habitat Complexity, an African Example

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Abstract

The relationship between increase in faunal diversity and corresponding increase in habitat complexity was quantified using shrubland bird communities in western Africa. Vegetational characteristics were measured in circular plots around bird positions. Bird species were then arranged from grassy open habitats to dense shrubland and found to be separated into three distinct communities when subjected to Duncan's multiple range procedure in conjunction with discriminant functions analysis. Random samples classified with respect to bird species showed there were few species in the more abundant open habitats and a disproportionate number of species were packed into the less common but complex shrubby habitat. The species packing formula generated supports the concept that spacial heterogeneity is a factor promoting high biotic diversity.

Introduction

It is well known that in most situations there are more species in tropical areas than at other latitudes. One reason for this, proposed by Ricklefs (1973), related to the possible existence of greater habitat complexity, or spacial heterogeneity, in the tropics than elsewhere. This complexity could proliferate ecological niches thus promoting specialization among organisms thereby reducing competition and allowing increased numbers of species to coexist in tropical environs. Using a crude foliage measure with respect to terrestrial avian populations, MacArthur and MacArthur (1961) showed that the species packing phenomenon is indeed related to degree of vegetational complexity. My study presented here describes a precise way of measuring species packing by birds in association with increased environmental complexity through the range of early successional habitats existing at a study site in Ghana, western Africa. Also, a method for separating avian communities is delineated.

Materials and Methods

The study was conducted from 12 November 1970 to 13 July 1971 in a mixture of disturbed habitats on the campus of University College of Cape Coast (now Cape Coast University) at Cape Coast, Ghana, in western Africa. The natural vegetation of the area is tropical lowland forest (Moreau, 1966) but little remained on campus or in the surrounding areas due to agricultural and urban developments interspersed with the successional recovery of vegetation on abandoned land resulting from rotational agriculture. This produced a mosaic of early successional stages in vegetation ranging from grassy areas, to open grassy shrubland, to very dense tall shrubland, interspersed with small untidy farm plots of maize, cassava, tomatoes, yams, peppers, pineapples and eggplants plus scattered citrus, pawpaw, banana and oil palm trees. There were no large areas of any one vegetational type, but rather scattered mixtures of small units of all stages. All these stages and conditions existed on campus, which was very large in size (several square miles) and included the university buildings, faculty housing, and several villages with adjacent farm lands and fallow areas. Only birds in the various successional habitats and crops were studied, eliminating all early and mature forest stands and forest edge. Thus, dense shrubby thickets 3-6 m tall constituted the most advanced vegetational type investgated. The overall landscape was mostly flat with some slightly rolling topography.

The methods and analyses employed were initially used in the present study in 1970-1971. Later, at my recommendation, they were adopted by Posey (1974) in northwestern Arkansas in 1972 and subsequently applied by me to studies in Nepal in South Asia (1981-1982), Belize in Central America (1988-1989), and northern Michigan (1987-1997), all part of an ongoing global study. Consult James (1992) for a detailed description of the field methods, which are identical to those employed in the present African study. This involved measuring 11 vegetational characteristics in circu-

lar plots 14.6 m in radius centered on exact positions where birds were found. There were 20 such plots sampled for each bird species. The vegetational characteristics included, 1) counting leaves that touched 8 levels marked on tall poles placed vertically at 40 random positions in the plot, the random spots drawn from random numbers indicating steps along each of 4 orthogonal transects from the plot center to its edge (10 positions per transect), the first transect positioned from a random twist of a compass dial, 2) the height of the tallest tree or shrub, 3) average vegetational height across the 4 sectors of the plot, 4) and stem density determined by the total woody stems intercepted in a foot wide plane at waist high along each of the orthogonal transects. An additional five vegetational pattern characteristics (stem evenness and variability, foliage vertical evenness, and foliage coarse and fine grained horizontal evenness) were calculated from the 11 measured in the field for a total of 16 vegetational factors (Table 1) associated with each of the 20 plots for each avian species. (The sampling method and the definition of all vegetational factors are described in great detail in James, 1992.)

Locating bird plots involved thorough and systematic searches of suitable areas having the diverse habitats mentioned above. Positions of both sexes, adults and subadults, of all species encountered were marked and plots were sampled later the same day. Birds were not marked individually, so sampling the same bird at different locations was possible. However, this repetition was minimized by sweeping through a given area only once and not repeating coverage. A total of about 61 hectares of suitable habitat was searched in the course of the study. Only local permanent resident birds were used, excluding the very rare species, also excluding those only seen flying over, seasonal migrants, and winter visitors from Europe. A total of 50 random plots without birds, nearly a plot per hectare of area covered, also was sampled in the study area to determine the nature of the actual vegetation present for comparison with habitats occupied by birds. Positions of random samples were located by drawing grids on maps of the various areas where bird plots were obtained and randomly selecting grid coordinates. Each segment of the overall study area was sampled in proportion to its relative size.

The data were analyzed with an IBM-360 Model 50 digital computer using statistical programs written by James E. Dunn, Mathematics Department, for the University of Arkansas mainframe system available in the 1970s. (All the routines mentioned below are examples of these programs.) The heterogeneous variance among the 16 vegetational variables was stabilized employing a program (Zodrow et al., 1988) developed from Box and Cox (1964) and Andrews et al. (1971) that transformed the original values. The arrangement of bird species in the vegetational complex and identification of important vegetational features were accomplished by subjecting the transformed data to multivariate analysis of variance (Morrison, 1967; Cooley and Lohnes, 1971) in conjunction with step-down analysis (Bargmann, 1962). Significance of separation of avian species along the first discriminant function axis was achieved by employing Duncan's multiple range procedure (Steel and Torrie, 1960). Each random sample plot was classified with respect to the various avian species habitats using quadratic discriminant function analysis (Anderson, 1958), and the regression relationship between habitat and avifauna was calculated using a program that performed a forward-selection polynomial fit.

Bird censuses were performed in the study area on a return to the campus in June 1978. Conditions looked remarkably unchanged then with some shifting of successional plots due to rotational agriculture. There were 4 census transects each 46 m wide and of variable length. The combined coverage totaled 16.56 hectares.

Results and Discussion

Twenty-three species of birds (Fig. 1) were common enough at the study site to obtain the 20 requisite sample plots. The resulting analysis showed that most the vegetational characteristics sampled in the avian plots were highly correlated with the first discriminant function, and most also were significant or nearly so (α=0.05) in separating the avian species along the discriminant axis (Table 1). Because all but one characteristic showed positive correlations, this indicates that vegetational density in nearly all strata varied from sparseness on one end of the axis to high density at the other end. The pattern is depicted in Fig. 1 showing an increasing shrubbiness progressing along the discriminant axis; open grassy areas on the left to tall dense shrubland on the right. The avian species are positioned along this progression (Fig. 1) determined by the mean discriminant scores for each. (The first discriminant function accounted for 54% of the overall variance, the second only 10% and decreasing from there, Wilks' Lambda $P<0.0001$.)

There was extensive habitat overlap in the plots for successive groupings of birds along the axis shown by results of Duncan's multiple range procedure (the various horizontal lines underscoring species groups in Fig. 1). For example, the lowest line at the lower right in the Figure extends under the tick marks for nine species positioned along the topmost line extending from *Lanius barbarus* to *Andropadus virens.* This shows that the vegetational plots for those species did not differ significantly (α=0.05). The next range line above that one drops the two right hand species and thereby picks up *Tockus fasciatus* to characterize a new group of eight birds that are essentially alike in habitat characteristics, and so on in stair step fashion to the left end of the Figure *Lanius collaris* on

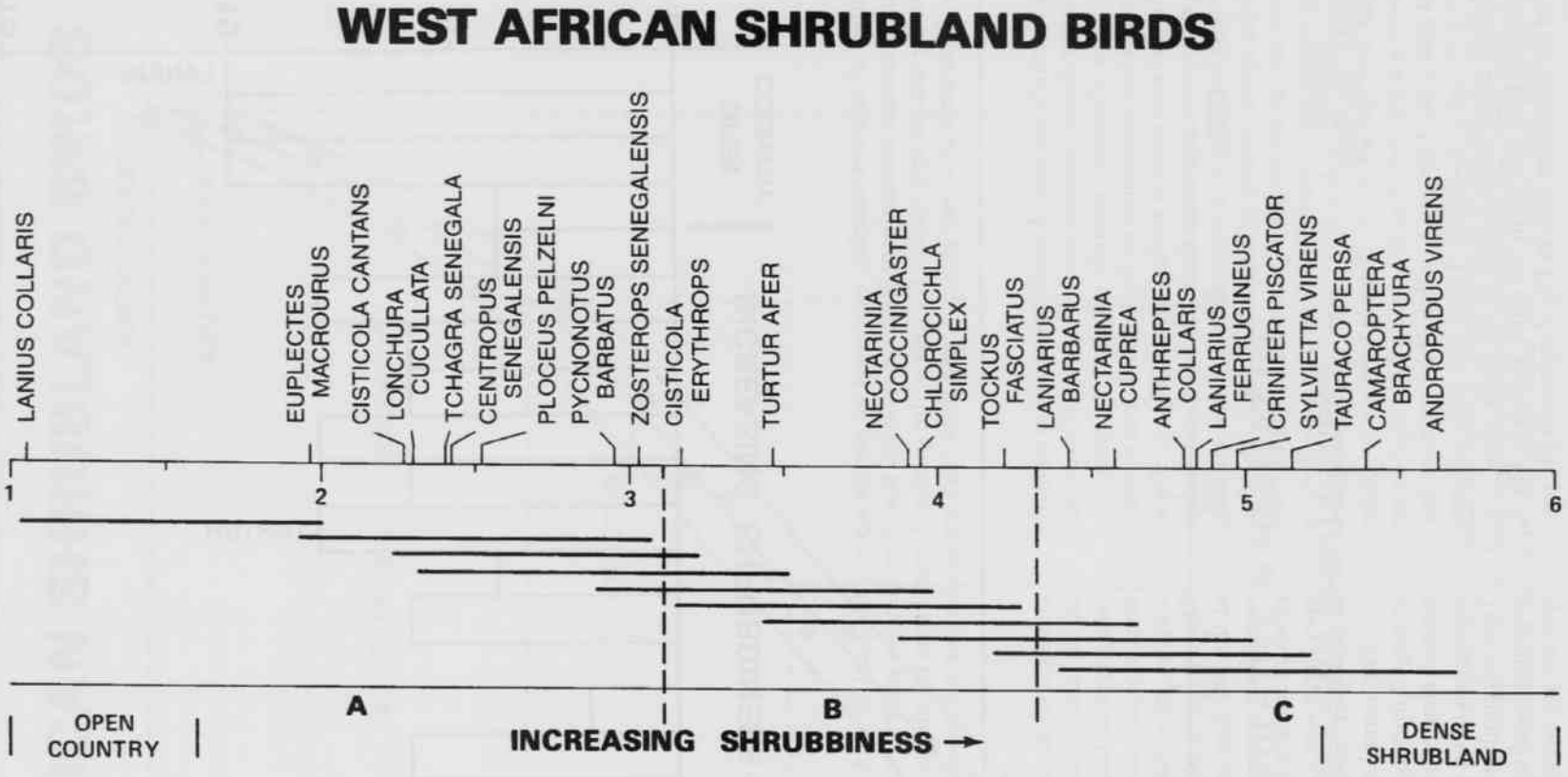

Fig. 1. Arrangement of bird species from open country to dense shrubland along the first axis produced by discriminant function analysis. The horizontal lines underscore groups of species that were not significantly different in habitat usage based on Duncan's multiple range procedure (α=0.05). The vertical dashed lines separate the three distinct avian communities that have nonoverlapping horizontal lines and thus occupy different habitats (explained in text). (English names of birds associated with scientific names are given in the Appendix.)

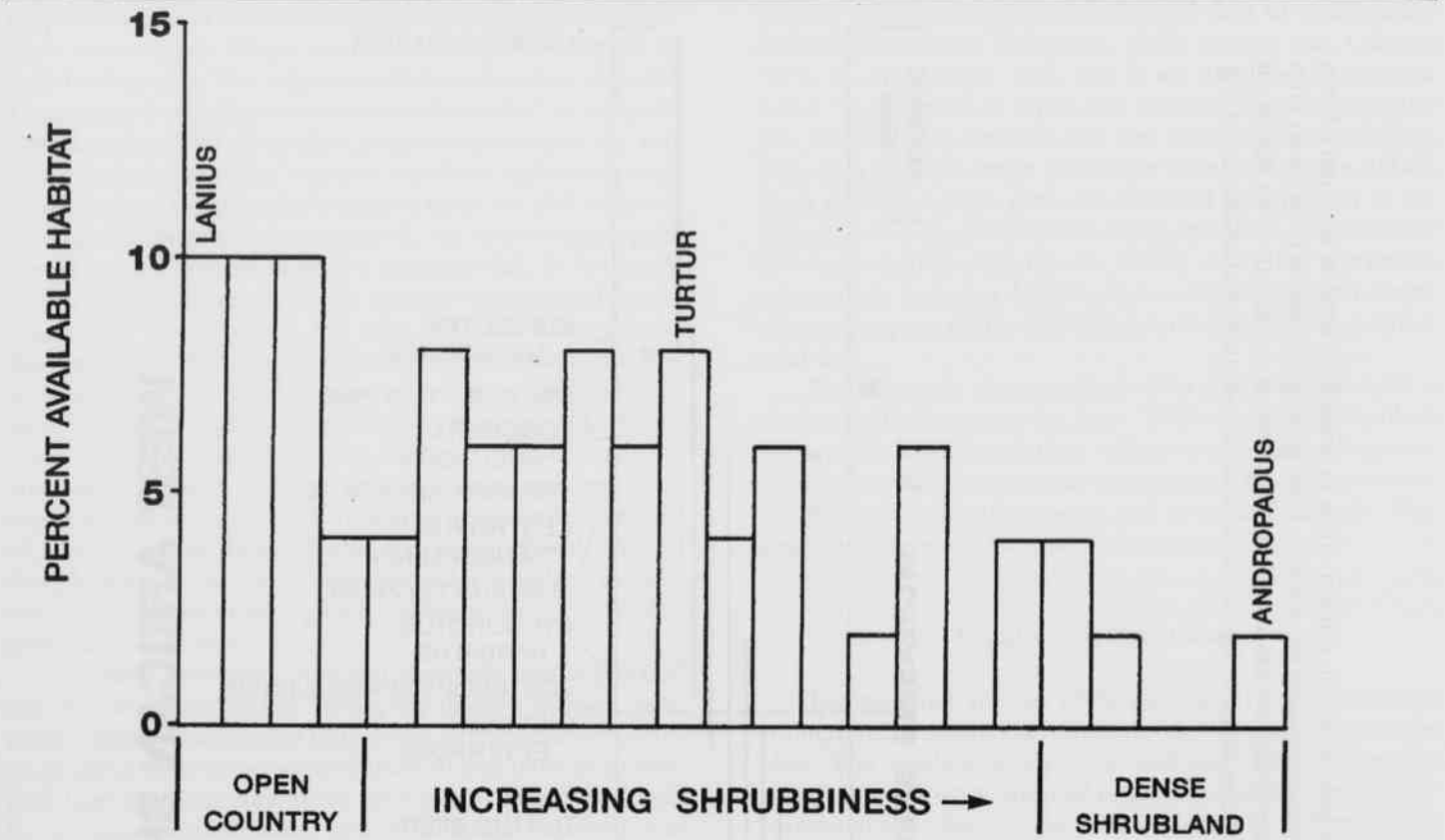

Fig. 2. Number of random samples, expressed as percentages of the total 50 such samples, that were classified for each bird species using quadratic discriminant function analysis. Random samples represent available habitat in the area, and there was no habitat in the sample appropriate for four of the species. Vertical bars for the species are arranged in order from open country to dense shrubland as shown in Fig. 1, and three bars are labeled for reference.

the far left just barely includes *Euplectes macrourus* in its habitat and these two barely overlap the next group of birds. All these range lines obviously broadly overlap, but there are three groups of birds subtended by lines that do not overlap (separated by the two vertical dashed lines in Fig. 1). These avian groups therefore represent three distinct communities of birds ($P<0.05$) existing in a vegetational mosaic showing transition from open country to dense shrubland. The first group of birds are on the far left represented by the top two overlapping range lines extending from *Lanius collaris to Zosterops senegalensis.* Now notice the sixth range line down that subtends five species from *Cisticola erythrops* to *Tockus fasciatus.* There is a gap between this one and the top two on the left, and also a gap between it and the bottom most line on the right previously described. These two gaps separate the three distinct avian communities in the study area.

Arranging the bird species in the order shown in Fig. 1, the heights of the histogram bars in Fig. 2 represent the percentages of the random sample habitat plots that were classified, using quadratic discriminant function analysis, as being typical habitat for each of the avian species. The random samples provide a representation of the proportions of various microhabitats actually present in the study area. More random plots fell in the open country end of the graph at the left than at the shrubland end to the right, and there were four species in the right half for which there was no random sample fit (Fig. 2). All this suggests that in the study area there was a greater percentage of available habitat that suited open country birds than shrubland ones.

The cumulative percentage of species (y axis, Fig. 3) arranged from open habitat to dense shrubland (Fig. 1) was plotted against (x axis) the corresponding cumulative percentage of open to dense habitat available shown in Fig. 2. This relationhip (Fig. 3) indicates that when 50% of the available habitat is accounted for only about 30% of the species are accommodated, and that the final 40% of the

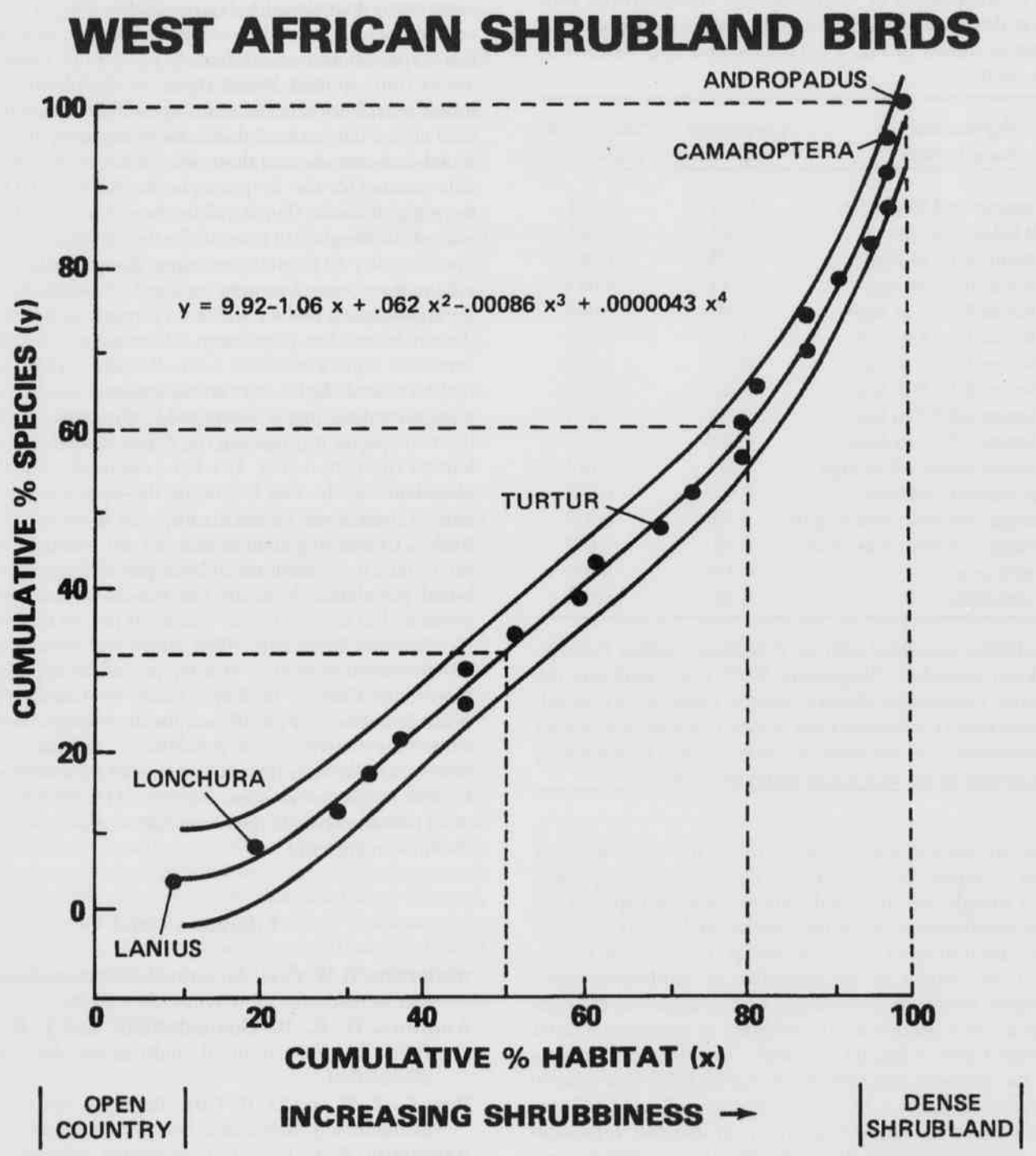

Fig. 3. Relationship between the accumulation of available habitat (abscissa) and accumulation of avian species present (ordinate) from open country to dense shrubland. The closed circles are bird species positions arranged in the same order as in Fig. 1. The formula given describes the best fit to the avian points shown by the center solid line. The outer solid lines are the 95% confidence limits. Dashed lines are described in the text.

Table 1. Correlations of 16 vegetational characteristics with the first discriminant axis, the axis that formed the avian ordination shown in Fig. 1 (characteristics fully defined in James, 1992).

Vegetational characteristic	Correlation coefficient	*Step-down probability
Avg. vegetational height (m)	0.667	0.001
Height tallest tree (m)	0.361	0.015
Total stems at 1.2 m high	0.743	<0.001
Total leaves 0-0.6 m high	-0.344	0.044
Total leaves 0.6-1.2 m high	0.380	0.003
Total leaves 1.2-1.8 m high	0.612	0.061
Total leaves 1.8-2.4 m high	0.629	0.605
Total leaves 2.4-3.0 m high	0.725	<0.001
Total leaves 3.0-3.7 m high	0.716	0.024
Total leaves 3.7-4.3 m high	0.588	0.012
Total leaves above 4.3 m high	0.473	0.012
Foliage vertical evenness	0.630	0.061
Horizontal evenness (coarse grain)	0.156	0.036
Horizontal evenness (fine grain)	0.276	0.037
Stem evenness	0.432	0.379
Stem variability	0.464	0.008

*Probabilities associated with the F statistics resulting from the step-down procedure (Bargmann, 1962) when analyzing the successive vegetational characteristics in order of corresponding correlations coefficients from highest to lowest, thus testing the significance of vegetational characteristics in separating avian species on the first discriminant function axis.

species are packed into the final 20% of the dense shrubby habitat (compare dashed lines in Fig. 3). If this regression were a straight line it would indicate that bird species are evenly distributed through the vegetational matrix, as is the case in the middle of this relationship (Fig. 3). This middle part of the habitat is representative of moderately open shrubland. However, the strongly curved upturn at the right end of the line documents the addition of species at a faster rate than there is habitat available. This relationship supports the concept proposed by Ricklefs (1973) that general increase in diversity is in part an outcome of increased spatial (two dimensional) heterogeneity, in this case represented by the complexity of dense shrubland compared to open grassland. The regression formula shown on Fig. 3 for the overall curve is a fourth degree polynomial that mathematically describes the species packing process, which is a rather tight relationship considering the narrow confidence limits shown.

Avian population data from the bird censuses in the study area gave contradictory results. Because there was more open than closed habitat available (Fig. 2) it is expected that open country birds would be the most abundant, and this expectation was confirmed by census results. Using *Turtur* (Blue-spotted Wood Dove) as the obvious dividing line (Fig. 2) between abundant open habitat and less abundant closed habitat available in the study area, the four combined censuses showed there was a total of only 64 individuals counted for the 12 species in the more closed habitat to the right of *Turtur* (Fig. 2) while there were nearly twice as many individuals (119 in total) for the 11 species in the more open country to the left (including *Turtur*). In fact, as noted above, there were four species (the four blanks in Fig. 2) in the more closed half for which no random samples matched their habitats. The population difference was highly significant (Chi Square = 16.52, 1 d.f., $P<0.001$). This conclusion that birds seeking the commoner habitats where indeed the more abundant ones is countered by the census findings that the two species terminating the dense shrubland end of the habitat ordination (Fig. 1) where essentially equal in high abundance to the two beginning the open country end (15 and 10 individuals counted compared to 13 and 13 respectively). Converting total counts for all censuses across all microhabitats to numbers of birds per 40 hectares, the combined population level for just the 23 commoner species examined in this study was 432 birds per 40 hectares.

ACKNOWLEDGMENTS.—The study was conducted when the investigator held a visiting professor appointment at University College of Cape Coast in Ghana. This was possible because of an off-campus duty assignment provided by the University of Arkansas in conjunction with a Senior Scholar Fulbright Award abroad administered by the United States Information Agency. Thoughtful comments from two anonymous reviewers added greatly to improving the final manuscript.

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Appendix. English names associated with scientific names used in text and Fig.s, listed in alphabetic order of scientific names (names according to Grimes, 1987).

Andropadus virens (Little Greenbul), *Anthreptes collaris* (Collared Sunbird), *Camaroptera brachyura* (Grey-backed Camaroptera), *Centropus senegalensis* (Senegal Coucal), *Chlorocichla simplex* (Simple Greenbul), *Cisticola cantans* (Singing Cisticola), *Cisticola erythrops* (Red-faced Cisticola), *Crinifer piscator* (Grey Plantain-eater), *Euplectes macrourus* (Yellow-mantled Widow-bird), *Laniarius barbarus* (Barbary Shrike), *Laniarius ferrugineus* (Bell Shrike), *Lanius collaris* (Fiscal Shrike), *Lonchura cucullata* (Bronze Mannikin), *Nectarinia coccinigaster* (Splendid Sunbird), *Nectarinia cuprea* (Copper Sunbird), *Ploceus pelzelni* (Slender-billed Weaver), *Pycnonotus barbatus* (White-vented Bulbul), *Sylvietta virens* (Green Crombec), *Tauraco persa* (Guinea Turaco), *Tchagra senegala* (Black-headed Bush-Shrike), *Tockus fasciatus* (Allied Hornbill), *Turtur afer* (Blue-spotted Wood-Dove), *Zosterops senegalensis* (Yellow White-eye).

In Vitro Growth Characteristics of Two *Cryptococcus neoformans* Isolates

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Abstract

Cryptococcus neoformans is an opportunistic pathogen which attacks individuals with weakened immune systems. Two *C. neoformans* isolates, 184A and NU-2, were examined to determine characteristics that contribute to their difference in virulence. Both isolates were grown under tissue culture conditions, and different characteristics were tested at timed intervals. Isolate 184A was found to grow at a faster rate than isolate NU-2, with doubling times of 4 and 12 hours respectively. The polysaccharide capsule of isolate NU-2 doubled in size in four hours, while that of isolate 184A stayed approximately the same. The NU-2 yeast cell diameter without the polysaccharide capsule was initially bigger than 184A at 3.62 pm and continued to increase although the diameter of isolate 184A stayed approximately the same at 2.41 pm. Isolate NU-2 shed excessive capsular material into the media, but isolate 184A shed little. These findings highlight some major differences in the characteristics of the two isolates which may contribute to the differing degrees of virulence.

Introduction

Cryptococcus neoformans is a ubiquitous yeast-like organism which causes cryptococcosis. The occurrence of this disease has increased in recent years due to the increase in immunocompromised individuals such as AIDS patients. Humans are frequently exposed to *C. neoformans,* yet the occurrence of cryptococcosis in immunocompetent individuals is relatively low. In contrast, individuals with depressed cell-mediated immunity (CMI) function due to chemotherapy, underlying malignancy, or infectious disease such as AIDS are extremely susceptible to a *C. neoformans* infection (Murphy, 1989). The organism is acquired through inhalation of the desiccated yeast cells in contaminated dust (Kwon-Chung and Bennett, 1992) and may cause an asymptomatic to mild pulmonary infection before it spreads to extrapulmonary sites. *C. neoformans* has a predilection for the central nervous system, and the majority of cryptococcal disease is diagnosed as meningitis or meningoencephalitis (Murphy, 1989).

There are four serotypes of *C. neoformans* (A, B. C, D), but virtually 100 percent of the AIDS patients in the United States with cryptococcosis are infected with serotype A cryptococci (Cherniak and Sundstrom, 1994). Among the many isolates of serotype A are cultures 184A and NU-2. These two isolates are known to be quite different from one another with respect to host clearance (Murphy unpub. observ.). In an experiment designed to display this difference, each isolate was injected intratracheally into naive mice. Sixty percent of the 184A infected mice survived to 95 days post-infection which was the end point of the experiment, but 100% of the NU-2 infected mice died by the 67th day of infection (Murphy unpublished observ.). In this situation, isolate NU-2 was clearly more virulent than isolate 184A.

This research focuses on determining the morphological and growth differences between these two isolates of *C. neoformans.* Knowing the combination of host and pathogen factors which are associated with either mild or severe disease may allow for the development of procedures which interfere with the virulence factors of the pathogen therebye reducing the incidence or extent of the disease in immunocompromised patients.

The first characteristic of the isolates examined was rate

of growth. One possible reason for the increased level of virulence observed in mice of isolate NU-2 over 184A may be due to faster rates of growth and reproduction. To test this possiblity, the growth rate of each isolate was determined under tissue culture conditions.

A second characteristic of the isolates that was examined was the diameter of the yeast cell without the polysaccharide capsule. The cell diameter with and without the polysaccharide capsule was measured, and the data from the two parameters was used to characterize the yeast cells.

A third characteristic that was examined was the kinetics of polysaccharide capsule formation. The presence of a polysaccharide capsule is known to contribute to the virulence of *C. neoformans* (Bulmer et al.,1967; Fromtling et al., 1982; Kozel and Cazin, 1971; Kwon-Chung and Rhodes, 1986). Both isolates have a polysaccharide capsule, but as time progresses in tissue culture medium, isolate NU-2 is able to increase capsule synthesis (Cherniak and Sundstrom, 1994). Using differential display PCR, differentially expressed genes for capsule production or other possible virulence factors can be examined. For this procedure, however, mRNA must be isolated, and the excessive capsule production of NU-2 can interfere with RNA isolation. By examining the kinetics of capsule production, the optimal time for RNA isolation–when the transcripts involved in capsule production are abundant, but little capsular material is produced–can be found. This will permit the study of the capsular genes which will be helpful in identifying virulence mechanisms. This in turn may allow for the augmentation of host resistance or therapeutic inhibition of the virulence factors.

The polysaccharide capsule production was also tested with a latex agglutination test. This test measures the amount of capsular material the isolate has shed into the culture medium. This will help determine when the isolates begin capsular production and the peak of that production. This along with the other data yields the optimal time for mRNA retrieval.

All of these factors may combine to make isolate NU-2 more virulent. The information obtained from these experiments may provide further insight into the causes of this virulence which could lead to more effective control of cryptococcosis.

Materials and Methods

Cryptococcus neoformans isolate 184A was isolated from the sputum of a patient at Charity Hospital in New Orleans, Louisiana in 1958. *C. neoformans* isolate NU-2 was isolated at the University of Nebraska School of Medicine, Department of Microbiology. Both isolates are serotype A with similar glucuronoxylomannan (GXM) structure and are alpha mating type.

Isolates were initially grown on Modified Sabourauds Agar (MSA) slants. For each experiment and isolate, three-day cultures were transferred to fresh slants and two days later used for the experiments. Isolates were washed off the MSA slants with sterile physiological saline solution (SPSS). Organisms were washed 3 times in SPSS and resuspended in RPMI, pH 6.8. They were then counted on a hemacytometer and resuspended at a concentration of 10^4 organisms/ml. One ml of the organisms in RPMI solution pH 6.8 was then added to each of three 14 ml tubes per isolate per time point. The inoculation of the tubes was done under the hood, and the tubes were incubated at 37°C, in a 7% atmosphere of CO_2.

The growth curve was determined by hemacytometer counts at 0, 4, 8, 12, 24, and 48 hours after inoculation. The number of *C. neoformans* cells/ml from the three tubes was averaged to obtain the mean for each time point.

The time points for the measurement of the diameter of the yeast cells without the polysaccharide capsules and the diameter of the polysaccharide capsules themselves were 0, 4, 8, 12, 24 , and 48 hours. At each time point the yeast cells in the inoculated tubes used for the hemacytometer count were measured. After the yeast cells were removed for the hemacytometer count, the rest of the solution was transferred to three 1.6 ml centrifuge tubes per isolate. The three tubes were centrifuged for 10 minutes at 600 g. Two-hundred µl of the supernatant fluid was removed from each of the tubes and pooled into a 1.6 ml tube and frozen at -20°C. Ten ul of remaining solution was put on a microscope slide with 37 µl of India Ink. A coverslip was then added. The diameters of the yeast cells both with and without the capsules were measured with an ocular micrometer. The diameters of the capsules were obtained by subtracting the diameters of the yeast cells without the capsules from the diameters of the yeast cells with the capsules. Approximately 100 cells/isolate were measured for each time point. These numbers were averaged to get a mean value for both measurements.

The Latex-Crypto Antigen Detection System (Immuno-Mycologics, Inc., Norman, OK) was used for the latex agglutination test or the soluble polysaccharide determination. Frozen supernatant was thawed for approximately 15 minutes; then 25 µl was added to the ring slide provided by the kit along with 25 µl of the Anti-Cryptococcus Globulin Reagent (ACGR). They were mixed and shaken at 100 rpm for 10 minutes. The reaction was then read according to the manufacturer's instructions. If the reaction was positive, 50 µl of the supernatant was added to 50 µl of a 1:10 dilution of the diluent with deionized water creating a 1:2 titer. Twenty-five µl of the 1:2 titer and 25 µl of the ACGR were added to a ring slide, mixed, and shaken for 10 minutes at 100 rpm. The reaction was then read. The dilution was increased log-

arithmically until a negative reaction occurred.

Means, standard errors of the means (SEM) and Student's t test were used for statistical analysis of the data. Results were considered significant if the *P* value was ≤ 0.05.

Results

The first objective of the experiment was to construct a growth curve for each isolate of *C. neoformans*. Separate cultures of each isolate were initiated with equivalent numbers of cells/ml. The hemacytometer count values were used to construct the growth curves. The mean values for cells/ml at each time point are shown in Fig. 1. The data from this experiment show that the doubling time for isolate 184A was approximately 4 hours while the doubling time of isolate NU-2 was approximately 12 hours. The data shown are representative of three experiments. These data demonstrates that isolate 184A reproduces more rapidly in culture than isolate NU-2.

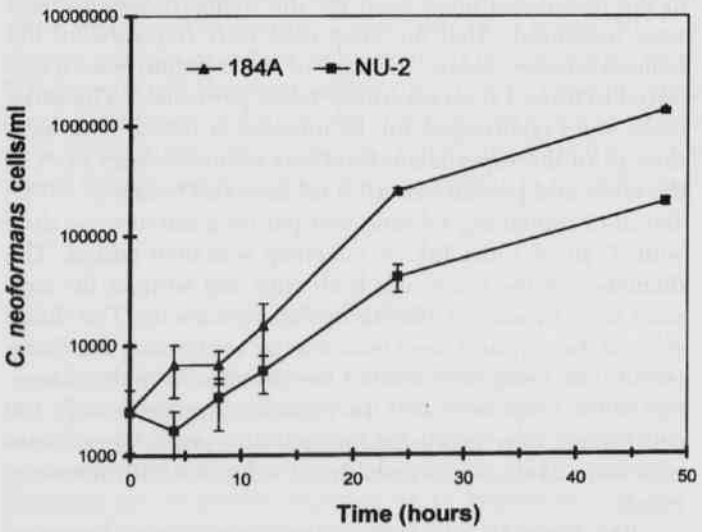

Fig. 1. Growth rate of *C. neoformans* isolates 184A or NU-2 in RPMI at 37°C in the presence of 7% CO_2. Error bars represent mean ± standard error of the mean of three determinations.

The diameter of the yeast cells without the polysaccharide capsule was another aspect of the two isolates that was measured. This measurement helped make the polysaccharide capsule measurements more significant because it showed a trend in the size of the inner part of the cells without the capsule. The mean values of the diameters of the inner part of the cells of the isolates at the successive time points are shown in Fig. 2. The cells of isolate NU-2 possessed diameters that were larger at time zero than isolate 184A and continued to increase in size whereas the diameters of the yeast cells of isolate 184A stayed relatively constant throughout the course of the experiment. These data represent two experiments.

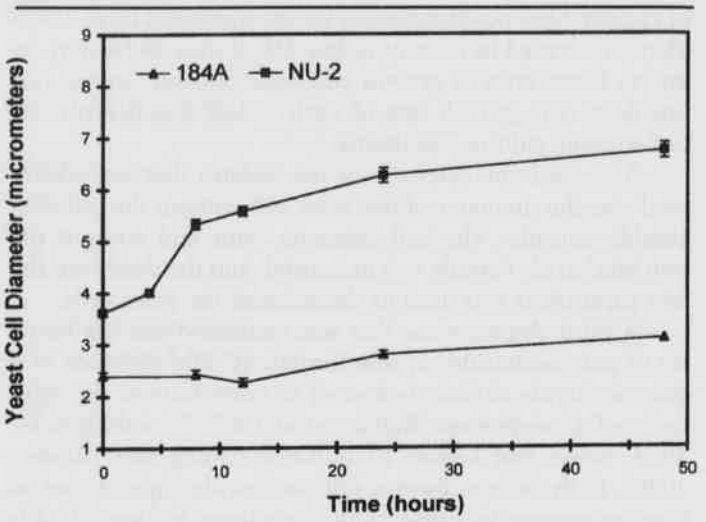

Fig. 2. Yeast cell diameter without the polysaccharide capsule for *C. neoformans* isolates 184A and NU-2. Error bars represent mean ± standard error of the mean of 100 determinants.

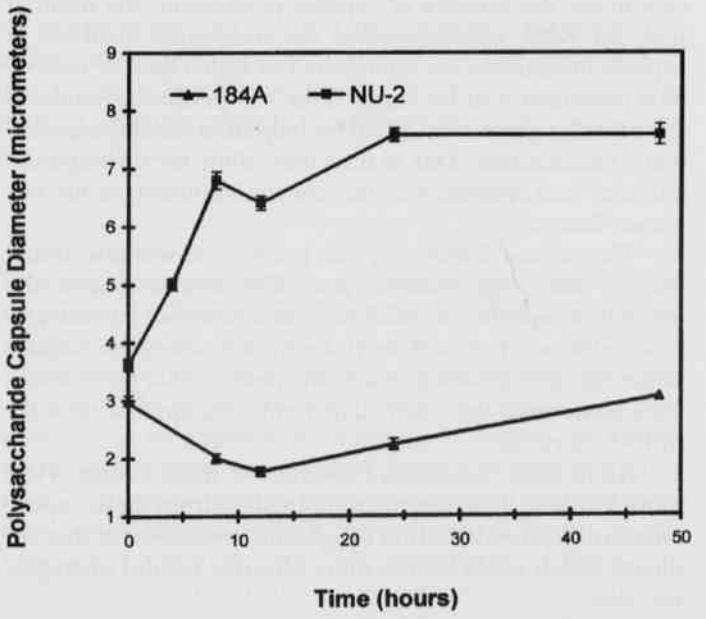

Fig. 3. Polysaccharide capsule diameter of *C. neoformans* isolates 184A or NU-2. Error bars represent mean ± standard error of the mean of 100 determinations.

Table 1. Latex agglutination results for *C. neoformans* isolates 184A or NU-2 at various time points.

Hours	Isolate 184A	Isolate NU-2
0	–	+ UNDILUTED
4	–	+ (1:4)
8	–	+ (1:32)
12	+ UNDILUTED	+ (1:128)
24	+ (1:64)[a]	+ (1:512)
48	+ (1:256)	+ (1:2048)

[a] Values are the titer from latex agglutination kit.

Next, we observed the kinetics of the polysaccharide capsular production. The mean values of the diameter of the polysaccharide capsule over 48 hours are shown in Fig. 3. By eight hours the average diameter of the yeast cells' capsules of isolate NU-2 had doubled while the mean diameter of capsules for isolate 184A had decreased slightly. Yeast cells of isolate NU-2 possessed capsule diameters that stayed roughly the same from 8 to 48 hours. The diameter of yeast cell capsules of isolate 184A did not change significantly during culture. These data represent two experiments.

Both isolates are known to have a polysaccharide capsule, but it is not clear at what point the capsule production peaks. A specific latex agglutination test was used to determine the amount of polysaccharide capsular material shed into the medium. Isolate 184A did not show a positive reaction until 12 hours (Table 1), but its titers did begin to increase at subsequent hours. Isolate NU-2 showed a positive reaction at zero hours which means that it probably was not washed well enough, but it continued to increase its titers by at least 2 increments at each subsequent time point. This demonstrates that isolate NU-2 is producing considerably more capsule than isolate 184A and is releasing it into the medium at a greater rate than isolate 184A.

Discussion

These data give growth rate estimates for two isolates of *C. neoformans.* The 184A isolate exhibits a much faster growth rate than the NU-2 isolate. This is an important difference in the two isolates. It has been postulated that isolate NU-2 is more virulent in mice than isolate 184A because it grows faster and simply overwhelms the host with cell numbers. The data present suggests otherwise. The growth rates also give the approximate doubling time of both isolates. Isolate 184A cell numbers doubled approximately every 4 hours, whereas isolate NU-2 cell numbers doubled approximately every 12 hours. These data suggest an optimal time of retrieving mRNA from the cells which would be after 4 hours for isolate 184A and after 8-12 hours for isolate NU-2. The doubling time is important for mRNA retrieval because the cells must be adequately growing and producing RNA. This doubling time will be considered with the time frame of the capsular production to find the optimal time for mRNA isolation.

The kinetics of the yeast cell size without the polysaccharide capsule is also an important difference between the two isolates because it too may contribute to the virulence of isolate NU-2 The greater cell size may cause the organism to occlude airways into the lung. The data from this experiment indicated that the yeast cell diameter without the polysaccharide capsule of yeast cells from isolate 184A stayed approximately the same throughout the 48 hour period. In contrast, the yeast cell diameter of isolate NU-2 increased over the first 24 hours and then leveled off. The question surrounding this proven growth in size of NU-2 cells is whether the cell is actually producing more protein material or just swelling with water intake. This is significant because if isolate NU-2 is producing more protein material, this material may contribute to its virulence. This mechanism is also significant because it could allow treatment for reducing the size of NU-2 to reduce pulmonary and dessiminated systemic infections. Further studies on the biomass will have to be completed to understand the mechanism by which cell size increases.

We also explored the production of the polysaccharide capsule. This is an important differing characteristic of the two *C. neoformans* isolates because the capsule is a factor in the virulence of isolate NU-2. A larger capsule may more effectively protect the yeast from host effecter cells such as alveolar macrophages in the lung (Bulmer and Sans, 1968; Swenson and Kozel, 1978). This experiment examined the kinetics of the capsular production. There was little capsule production by isolate 184A while isolate NU-2 produced excessive amounts of capsule, especially within the first eight hours. Using this information, the optimal time to extract capsule gene mRNA from isolate NU-2 without the interference of excessive capsular material would be in the

first eight hours. More kinetic studies with smaller time intervals would be needed to find the specific optimal time point in this eight hour span.

A latex agglutination test was also performed to observe the kinetics of capsular material that was shed into the culture medium. It is well documented that increasing cryptococcal antigen titers are characteristic of a poor prognosis while decreasing antigen titers signify a good prognosis (Diamond and Bennett, 1974). Excess capsular polysaccharide likely affects host reactivity. The experiment results show that isolate NU-2 was producing and shedding capsular material throughout the entire experiment. The titers were constantly increasing which confirms the results from the measurement of the actual polysaccharide capsule. These data help to explain why isolate NU-2 is more often fatal than 184A in experimental animals. Isolate 184A did not begin producing capsular material for 12 hours but the titers increased thereafter. This fact seems to indicate that an optimal time for RNA retrieval from isolate 184A would be after 12 hours, and the RNA from isolate NU-2 should be retrieved as soon as possible. More precise experiments with smaller time intervals will have to be done to get the precise time when the isolates are both actively growing and reproducing and not producing excessive capsular material. These data narrow down the optimal time for retrieval, but it is still quite broad.

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Effects of Agricultural Practices on Nutrient Concentrations and Loads in Two Small Watersheds, Northwestern Arkansas

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Abstract

The water quality of two small, adjacent watersheds was monitored to determine the effect of land use on nutrient loads and flow-weighted mean concentrations. Poultry litter and liquid swine waste are surface applied as fertilizer to pastures that are used for hay production and beef cattle grazing. The study area is located in northwestern Arkansas, east central Washington County. Cannon Creek, the less influenced watershed (628 hectares), contains 11% pasture; whereas, Shumate Creek, the more influenced watershed (589 hectares), contains 22% pasture and receives approximately four times more land-applied animal waste as fertilizer. The remaining land cover in both watersheds is primarily hardwood forest. Shumate Creek had higher nutrient concentrations and greater nutrient mass transport. Stormflow transports a larger percentage of the nutrient load than baseflow; e.g., during the month of April more than 30% of the total phosphorus (TP) load was transported in less than four days of storm flow at the Shumate Creek site. The total pasture area, the proximity of pastures to streams, and the intensity of pasture management (i.e., the rate and timing of manure applications) are important aspects to consider when monitoring water quality.

Introduction

The water quality of the White River is of special interest since it flows into Beaver Lake, which is the domestic water supply for much of Northwest Arkansas. There is the potential for agricultural non-point source (NPS) pollution due to the agricultural activity in the drainage basin of the White River. The Upper White River Best Management Practice (BMP) Implementation Project is a multi-agency project that was formed in March 1994 to help with the installation and monitoring of agricultural BMPs to help improve water quality. Water quality parameters were measured to monitor the effect of land use on water quality, to evaluate the importance of stormflow when studying water quality, and to determine the effectiveness of the BMPs. Two tributaries of the White River, Shumate Creek and Cannon Creek, were monitored in this study. The two sampling sites are located on the edge of Washington County in Northwest Arkansas, south of Durham and accessed from Arkansas Highway 16. Samples collected at Cannon Creek (Sec. 8, T14N, R28W) represent the less influenced or control site. Shumate Creek (Sec. 32, T15N, R28W) represents the more influenced site and shows the impact of agricultural operations, which are currently implementing best management practices. Non-point source pollution indicators (i.e., increases in phosphorus and nitrate levels) at Shumate Creek should decrease in concentration and/or mass transport as the best management practices are implemented. This statement is consistent with data from five stream monitoring sites collected from September 1991 to April 1994 elsewhere in Northwest Arkansas (Edwards et al., 1994). That particular study observed decreasing trends (from 14 to 75% per year) in average stream flow concentrations of the

nitrogen forms, nitrate-nitrogen (NO_3-N) and ammonia-nitrogen (NH_3-N).

The two watersheds are similar in area, soils, relief, and geology. Shumate Creek watershed is 589 hectares and Cannon Creek watershed is 628 hectares. The soils are classified as being deep to shallow, moderately drained to somewhat excessively drained, gently sloping to steep (USDA, 1969). The variability in the soils is contributed to the relief, approximately 259 meters in both basins, which results in different soils on ridges and slopes. Horizontally bedded Pennsylvanian aged sedimentary rocks characterize the geology of both basins. Specifically, the geology is limestone, sandstone, and shale of the Brentwood member of the Bloyd Formation and the Cane Hill and Prairie Grove members of the Hale Formation.

Two important differences between the sub-basins with regard to water quality are the amount of pasture in each and the distribution of the pastures. Shumate Creek, having 22% pasture lands, is more influenced by agricultural practices. Cannon Creek is the less influenced site comprising only 11% pasture. Geographic Information Systems (GIS) land use maps were reviewed for actual percentages of agricultural vs. forested areas in the two drainage basins. Edwards et al. (1996) reported that mean concentrations of dissolved orthophosphate ($P0_4$-P), total phosphorus (TP), and total suspended solids (TSS) were highest for sub-basins with the highest proportions of pastureland use. In addition, the pastures in Shumate Creek basin are along the floodplain; whereas, the pastures in the Cannon Creek basin are on ridge tops with riparian forest along the stream.

Materials and Methods

Data were collected from April 1996 to March 1997. Samples were collected during storm events using Sigma® automated samplers. An increase in stream stage triggers the sampler to begin collecting. Grab samples were taken monthly and following storm events. The samples were then retrieved and delivered within 24 hours to the Arkansas Water Resources Center Water Quality Laboratory, which is certified by the Arkansas Department of Pollution Control and Ecology (ADPC&E) for wastewater and the Louisiana Health Department for drinking water. All samples were analyzed for the following parameters:

Nitrate-nitrogen (NO_3-N)
Ammonia-nitrogen (NH_3-N)
Total phosphorus (TP)
Dissolved orthophosphate (PO_4-P)
Total suspended solids (TSS).

All analyses were performed according to Standard Methods (APHA, 1992).

Loads and flow-weighted mean concentrations were calculated for the water quality parameters that were monitored in the study. Load represents the total mass (kg) of each parameter that is moving by a point in the creek within a given period of time. It was calculated by multiplying the concentration of a parameter by the volume of discharge at the time of the concentration, then summing the results for the month and year. Discharge was recorded every 15 minutes using a pressure transducer to measure stage. Storm and grab sample concentrations were applied to the time interval when collected. Concentrations were applied to each 15-minute discharge reading by extrapolating between the data from storm and grab samples. Estimation of load is useful when evaluating effects on the water quality of Beaver Lake because it represents monthly and/or yearly totals of a substance that are moving into the system and accounts for the effect of discharge.

Flow-weighted mean concentrations were calculated by dividing the monthly load by the monthly discharge. This normalized the concentration for discharge differences that occur between the two watersheds (Fig. 1). Flow-weighted mean concentrations are useful when investigating the effect of land use on the water quality of the two tributaries.

Results and Discussion

Land use (i.e., riparian zones and amount of land-applied animal waste) in the drainage basins of Shumate and Cannon Creeks has impacted water quality. Shumate Creek has more agricultural use in its drainage basin and approximately four times more land-applied animal waste than Cannon Creek. Data indicated higher loads and flow-weighted mean concentrations in Shumate for most parameters. In several Buffalo River tributaries, nitrate concentrations were found to be related to percent pasture, as well as specific pasture management (Mott, 1997). The flow-weighted mean concentrations of nutrients, which are indicators of pollution from animal waste, were two to four times higher in Shumate Creek than Cannon Creek, (Fig. 2-4). For example, in May 1996 the flow-weighted mean concentration of nitrate-nitrogen was 0.3 mg/L at Cannon Creek and 1.25 mg/L at Shumate Creek. The mean concentration of nitrate-nitrogen for a pristine upper Buffalo River site varied from 0.04 mg/L during baseflow to 0.01 mg/L during stormflow (calculated from the National Buffalo River Database, 1998). This verifies that the intense agricultural practices in the watershed of Shumate Creek are affecting its water quality.

Stormflow is responsible for transporting a considerable percentage of total loads. Increased discharge corresponds with increased loads and substantially higher concentrations. For example, during an April 1996 storm at Shumate watershed, TSS concentrations increased from approxi-

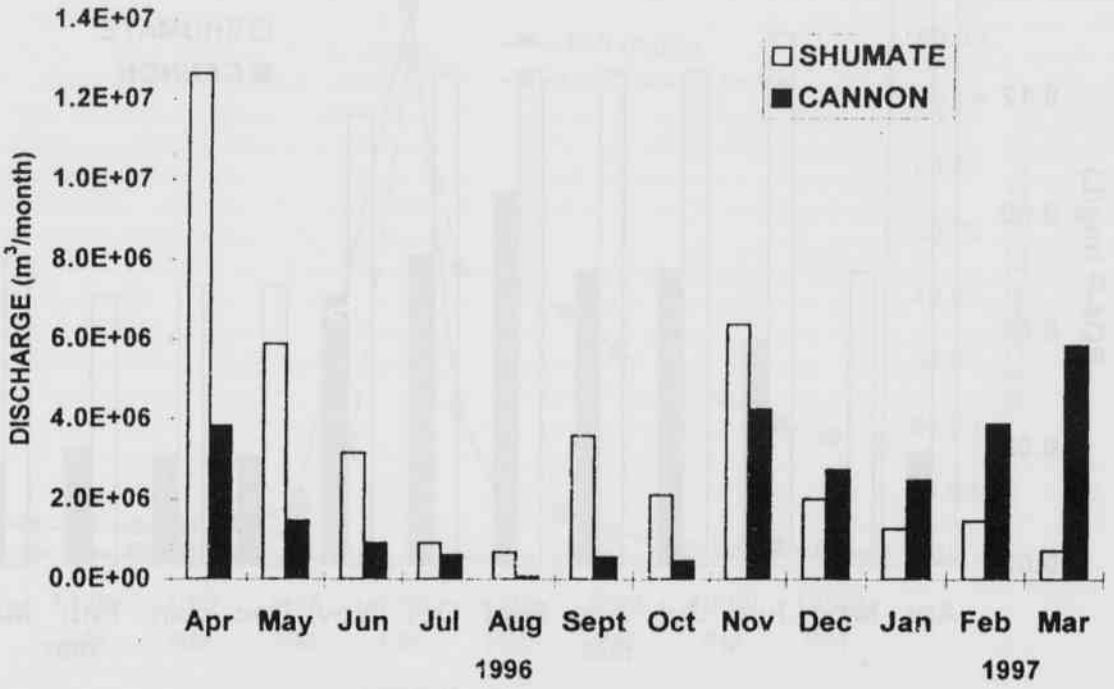

Fig. 1. Discharge for Shumate and Cannon Creeks.

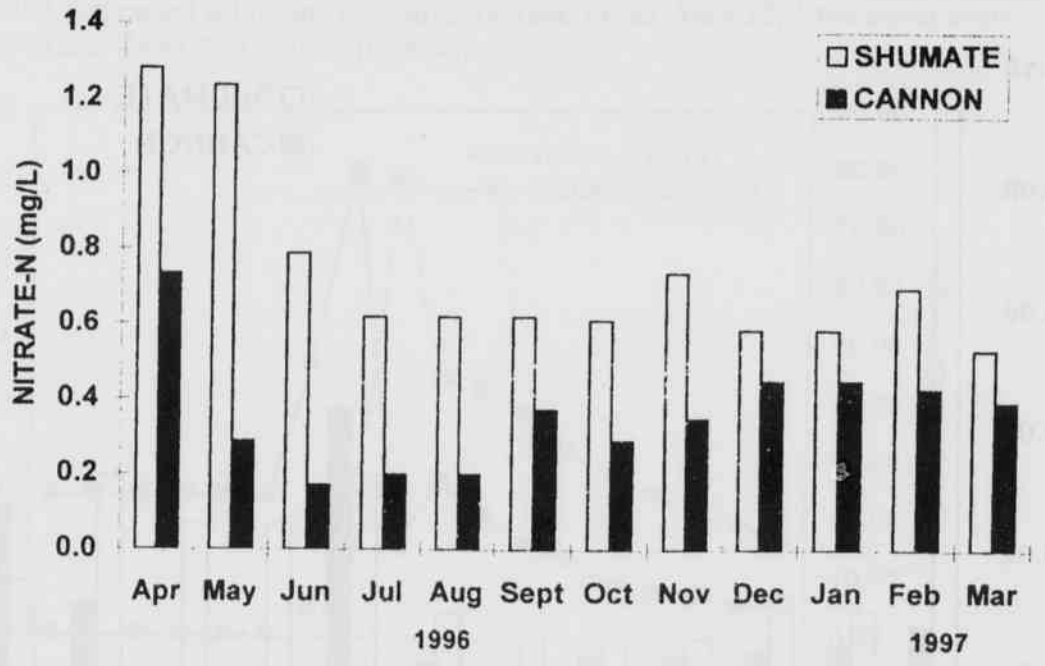

Fig. 2. Flow-weighted mean concentrations of nitrate-nitrogen in Shumate and Cannon Creeks.

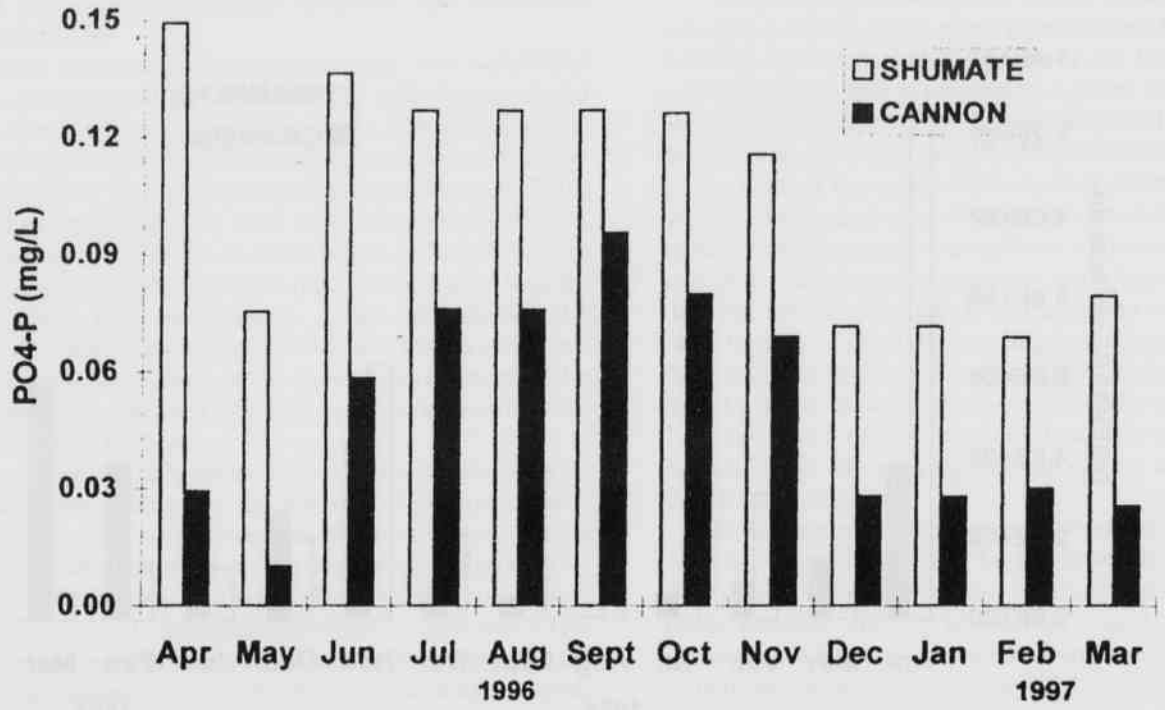

Fig. 3. Flow-weighted mean concentrations of dissolved orthophosphate in Shumate and Cannon Creeks.

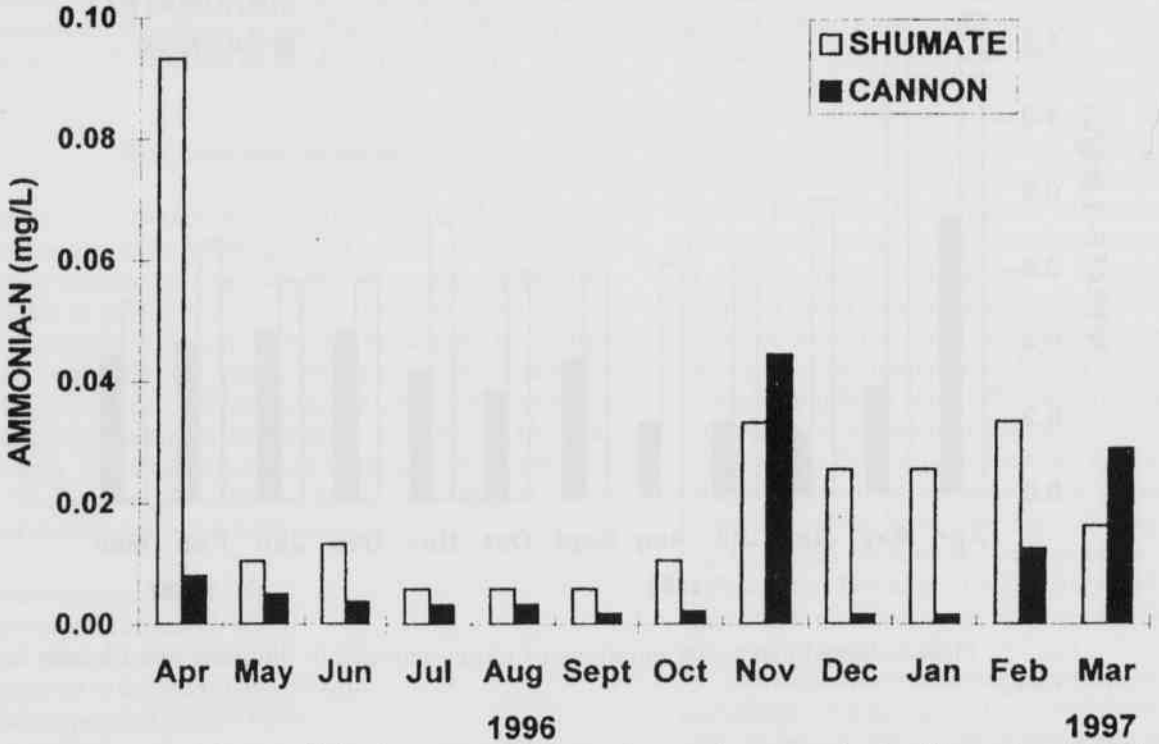

Fig. 4. Flow-weighted mean concentrations of ammonia in Shumate and Cannon Creeks.

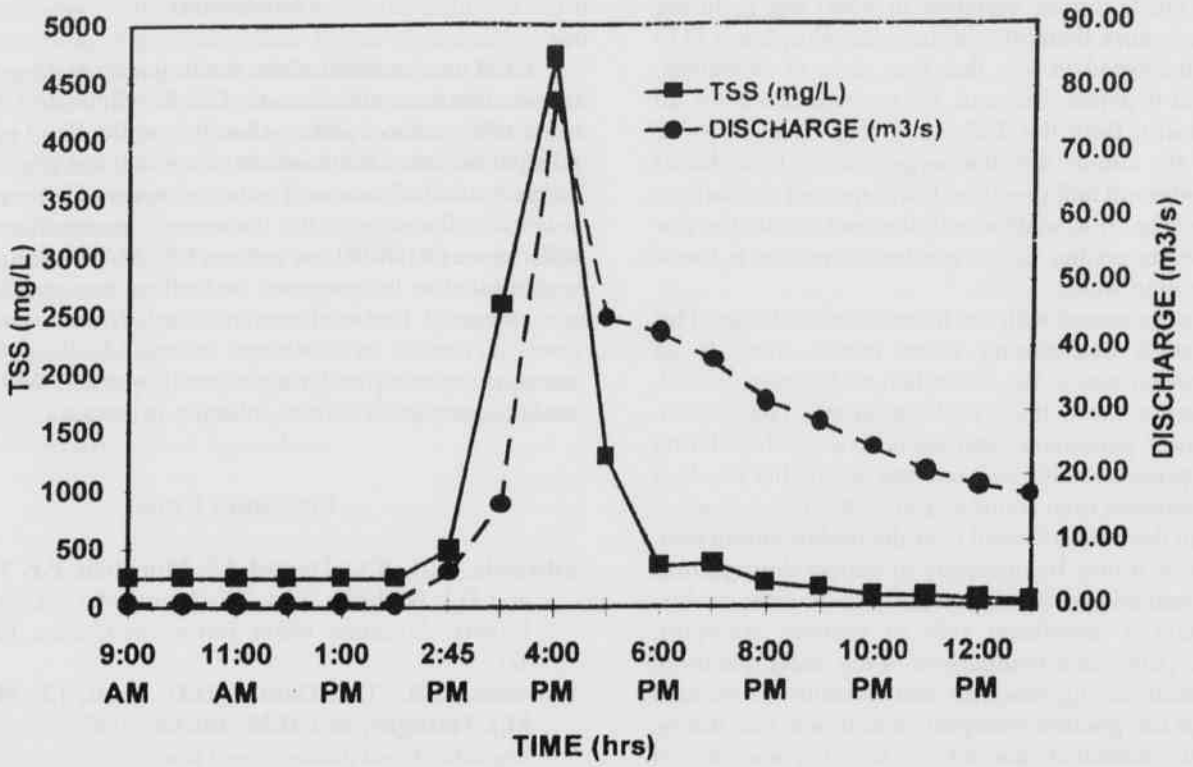

Fig. 5. Total suspended solids and discharge vs. time for an April 12, 1996 storm event at Shumate Creek. Note TSS mimics the discharge.

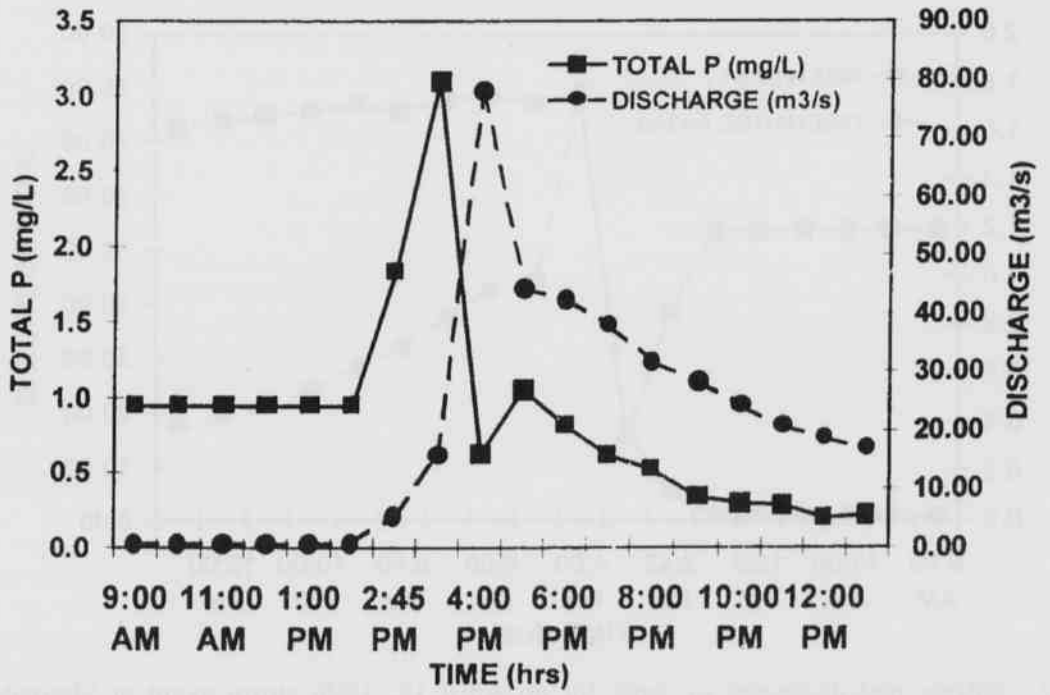

Fig. 6. Total phosphorus and discharge vs. time for and April 12, 1996 storm event at Shumate Creek. Note TP mimics the discharge.

mately 250 mg/L during baseflow to 4500 mg/L during stormflow and more than 30% of the total phosphorus (TP) load was transported in less that four days of stormflow. Figures 5 and 6 depict TSS and TP concentrations for an individual storm. Both the TSS curve (Fig. 5) and the TP curve (Fig. 6) mimic the discharge curve. Phosphorus adheres to sediment and therefore is transported similarly to TSS. Nitrate (Fig. 7) is soluble and does not mimic the discharge curve suggesting that a portion of nitrate is transported by ground water.

Load also increased with the increase in discharge. This is an indication that during storm events there is an increased erosion rate in the watershed and excessive loading of sediments (Mott, 1997) to the tributary. The concentrations of most parameters increased considerably during stormflow. Spring and fall rainy seasons had higher levels of selected parameters than summer and winter dry periods.

Although the data collected over the twelve-month period indicate that it may be necessary to sample during storm events to obtain an accurate representation of water quality, baseflow plays a significant role in nutrient transport. Owens et al. (1991) in a comparison of the water quality of four watersheds during baseflow and stormflow, indicated that although the greatest transport of nutrients was during stormflow, a substantial amount, 25 to 50%, was moved during baseflow. Therefore, it is important to sample during both stormflow and baseflow to obtain the most accurate information.

Conclusions

Land use has affected the water quality of these two tributaries, Shumate and Cannon Creeks. Shumate Creek had more total pasture, pastures located on the flood plain with no riparian zone, more intensive agricultural practices, and higher nutrient loads and concentrations. There were also seasonal influences on the loads and concentrations due to differences in rainfall, as well as times when animal waste was applied to the pastures. Stormflow transported a large percentage of the total nutrient load. Nutrient concentrations increased as discharge increased. It is therefore necessary to sample during stormflow and baseflow when studying non-point source pollution in streams.

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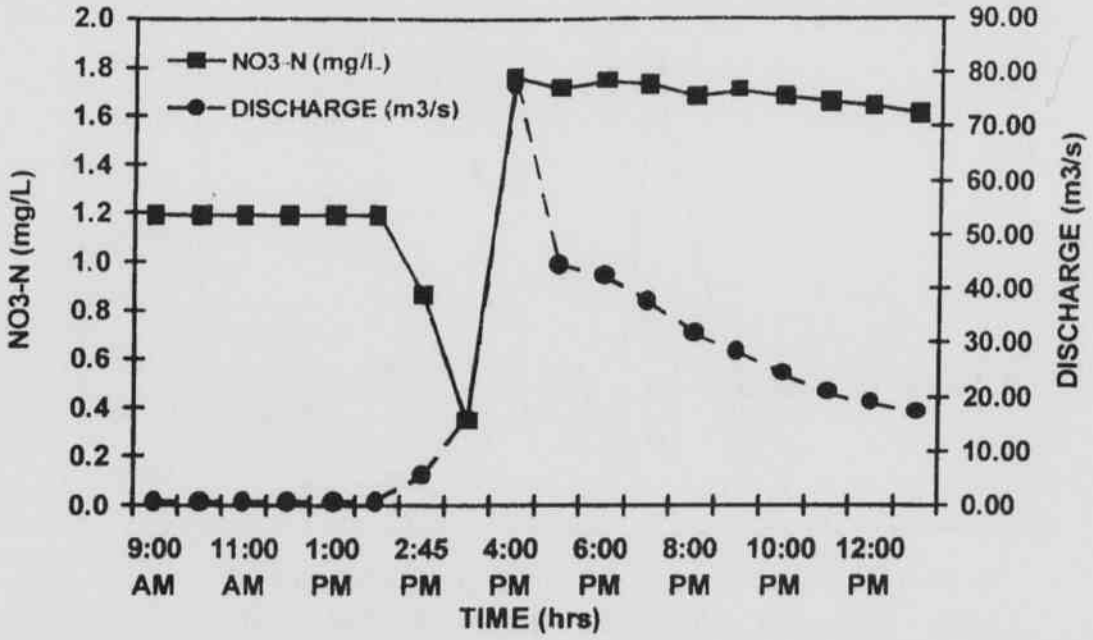

Fig. 7. Nitrate and discharge vs. time for an April 12, 1996 storm event at Shumate Creek. Note NO3-N doesn't mimic the discharge.

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Notes on the Natural History of *Lasiurus borealis* in Arkansas

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Abstract

Since June 1982 we have studied various aspects of red bat ecology in Arkansas with emphasis on field work in the Ouachita Mountains and examination of specimens submitted to the Arkansas Department of Health Rabies Laboratory (ADHRL). This study reports on continued field work in the Ouachita Mountains using radiotelemetry and updates information regarding red bats submitted to the ADHRL through December 1996. In addition, we revisited a cave previously reported to contain a large number of red bat skull and skeletal remains. We also report remains from another cave system in north-central Arkansas. These investigations have yielded additional information on distribution, growth and development of young, litter size, use of atypical roosts, active period and hibernation roost site selection, copulation, and incidence of rabies.

Introduction

The red bat, *Lasiurus borealis*, is one of Arkansas's most common woodland bats, yet relatively little information is available regarding its natural history in Arkansas or elsewhere. For example, the *Proceedings* of the Bats and Forests Symposium held in Victoria, British Columbia, Canada (Barclay and Brigham, 1996) contains twenty-two papers, yet none pertain to red bats, and Nagorsen and Brigham (1993) allow that "scanty information" is available concerning the red bat in Canada. The secretive behavior of this solitary species probably accounts for the paucity of observations. Red bats do not form colonies; they roost individually in trees where they are rarely visible and infrequently encountered and almost never utilize buildings, mines or caves. Therefore, locating sufficient numbers of these bats on a regular basis for protracted and continuous study is extremely difficult. The result of all of these contributing factors is that most information regarding this species is of a fragmented nature and typically consists of records of individuals or females with offspring, providing researchers limited glimpses into the annual cycle of this beautiful tree bat.

Sealander and Heidt (1990) considered the red bat to be abundant and occur state-wide. They reported specimens from 34 counties. Baker and Ward (1967) regarded the red bat as the most common bat in southeastern Arkansas after they captured 177 in six nights during August. Gardner (1978) reported red bats as the most commonly encountered species in the Delta region of northeast Arkansas. They constituted 85 percent (81/95) of all bats captured during his study, and Paige (1981) reported red bats constituted 63 percent of bats captured in the Salem Plateau of northcentral Arkansas. Red bats represented 29 percent of bats captured in an urban park setting in Hot Springs, Arkansas (Saugey et al., 1988), and Saugey et al.(1989) reported red bats as the most frequently mist-netted bat in forested areas of the Ouachita Mountains where 386 individuals were captured. Steward (1988) found red bats to be one of the most common bat species in southwest Arkansas having captured 53 specimens, and Caire (1986) reported red bats comprised 35 percent of bats captured during his study in southeast Oklahoma. Clearly, these studies support the contention red bats are abundant and widespread in all regions of Arkansas. And because of their abundance, red bats undoubtedly play an important role in the ecology of Arkansas at the ecosystem level as predators of night-flying insects. The purpose of this study was to provide additional distribution, natural history and incidence of rabies data concerning the red bat in Arkansas.

Materials and Methods

The majority of data reported here was derived from the study of red bats submitted to the Arkansas Department of Health Rabies Lab (ADHRL) between June 1982 and December 1996. During this period a total of 521 specimens (Table 1) from 59 counties were recorded. Red bats represented 40 percent (521/1294) of all bat specimens submitted to the ADHRL during this 15 year period. This sample included juveniles and adults of both sexes, pregnant speci-

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Table 1. Red bats submitted to the Arkansas Department of Health Rabies Laboratory, 1982 - 1996.

MONTH	# SUBMITTED	MALE	FEMALE	UNKNOWN
JANUARY	3	2	1	0
FEBRUARY	2	2	0	0
MARCH	16	13	3	0
APRIL	38	11	26	1
MAY	29	10	17	2
JUNE	168	56	111	1
JULY	124	43	76	5
AUGUST	58	18	35	5
SEPTEMBER	38	18	17	3
OCTOBER	28	15	13	0
NOVEMBER	14	11	1	2
DECEMBER	3	2	1	0
TOTAL	521	201	301	19
PERCENT		38.6	57.8	3.6

mens, adult females with litters, and litters without adult females. Nineteen specimens were submitted as "heads only" for identification purposes, and sex could not be determined: the collection localties of seven specimens were not available. As expected, the greatest number of submissions were from densely populated urban areas where bats are much more likely to be encountered by humans and their pets.

Unfortunately, many of the pregnant specimens were not examined internally to determine numbers and sexes of fetuses due to their advanced states of deterioration or their battered conditions. Early in the study, forearm lengths and written descriptions of newborns and juveniles were not incorporated into the database because our goals at that time were to determine identity, sex, and geographic distribution within the state for ADHRL records.

Other specimens were collected by mist netting as described by Kunz (1988). Nets of different lengths (5.5, 12.8 and 18.3 meters[m]) were erected and opened into the capture position prior to dusk and checked at frequent intervals. Netting primarily occurred over shallow pools of streams and across abandoned roads in the Ouachita National Forest, Arkansas. Few mist-netted red bats were retained as museum voucher specimens. Instead, these bats were banded using yellow plastic split-ring bird leg-bands from A.C. Hughes, Middlesex, England. Thirteen red bats were fitted with .71 gram(g), 21-day battery-life radiotransmitters manufactured by Holohil Systems, Ltd. of Carp, Ontario, Canada. Radio-tagged bats were tracked using CE-12 and Merlin-12 receivers and five-element Yagi antennaes manufactured by Wildlife Materials, Inc. of Carbondale, Illinois. Distances between roost sites were determined using a *Trimble* Navigation Scout Global Positioning System receiver. Skeletal remains were collected by hand from caves and buildings. Voucher specimens were deposited in the Museum of Zoology Collections at the University of Arkansas at Little Rock and Arkansas State University, Jonesboro.

Results

Atypical Roost Sites.--Red bats are considered tree bats and are rarely encountered in caves, mines or buildings. However, on occasion this species has been found to utilize what are considered to be atypical roosts. In 1977 McDaniel and Gardner reported red bat remains from Blanchard Springs caverns and Hell Creek cave in Stone County. Saugey et al. (1978) reported the remains of 140 red bats in a side passage of Rowland Cave also in Stone County. In January 1993, 15 years after the original report of red bat remains in Rowland, the cave was revisited. Scattered about this same passage were the remains of only 10 red bats, all in an advanced state of deterioration that precluded determination of sex. Although the rate at which red bats enter this chamber is unknown, the low number encountered suggests significant accumulations may occur over a long period of time. We also report the discovery of three red bat skulls collected from Cushman cave in Independence County on 5 October 1991.

The occurrence of red bat remains in Arkansas cave systems should not be surprising. Cassidy et al. (1978) reported 18 red bats collected during mist netting activities during late summer and early autumn swarming activity at two Arkansas Ozark caves. Saugey (1978) reported the capture of 77 red bats in mist nets during swarming activity at Rowland cave between 14 July and 27 October of 1977.

Saugey and England (unpublished data) have recovered the intact carcasses of two male red bats from the attic of an abandoned house in Columbia County. One specimen was collected during each October of 1990 and 1991. The attic was regularly used as a daytime roost by Rafinesque's big-eared bat (*Corynorhinus rafinesquii*) and was accessible only by entering the lower portion of the house and then passing through a 1 x 1.3 m opening in the ceiling. Considering the time of the year these specimens were encountered and their lack of deterioration, one may speculate that the fall aggregation activities of *Corynorhinus* or other bat species at this structure may have attracted these red bats who were unable to locate the exit and perished. The presence of red bats during swarming activities of other bat species in Arkansas and elsewhere may be the result of their apparent attraction to the vocalizations of conspecifics and other species (Baker and Ward, 1967; Barbour and Davis, 1969; Downes, 1964; Mumford and Whitaker, 1975; Saugey at al., 1988; Saugey et al., 1989).

Rabies.--In Arkansas, red bats test positive for rabies more frequently than any other bat species based upon the

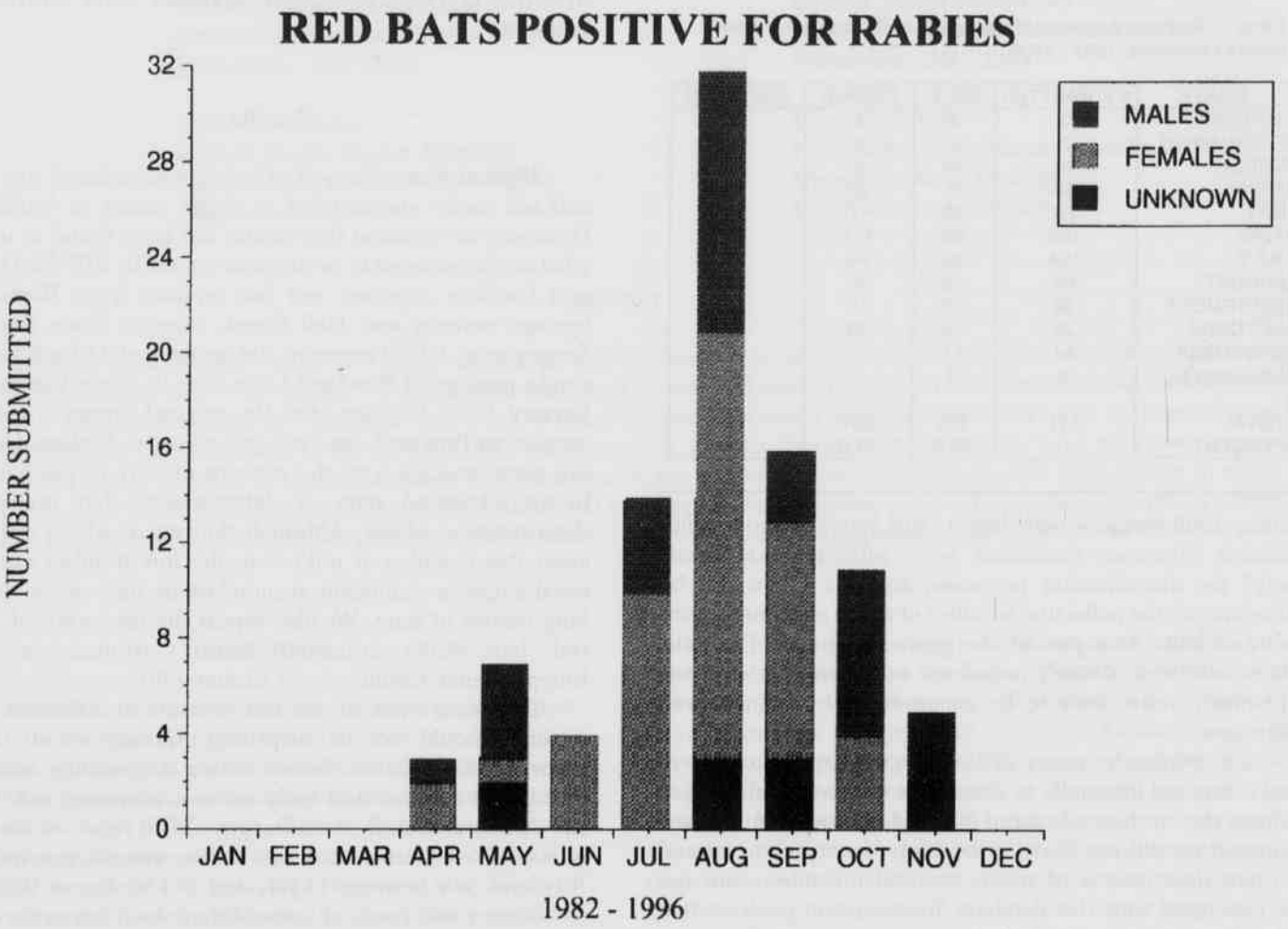

Fig. 1. Red bats reported positive for rabies in Arkansas, 1982 - 1996.

available sample size. Heidt et al. (1987) summarized bat rabies in Arkansas for the period 1982-1986 during which time red bats positive for rabies were reported from 23 counties. In 1991 Heidt et al. updated animal, including bats, rabies data for the state, but did not specifically address additional county occurrences for the red bat. Since 1986, 14 additional counties have had red bats test positive for rabies, and a number of previously reported counties have had additional cases confirmed bringing the total to 92 positive specimens (17.7%) of 521 red bats submitted (Fig. 1). County affiliation of two of these positive specimens is unknown. These 37 counties and the number of positive specimens are Arkansas (2), Ashley (1), Benton (3), Clark (3), Cleburne (2), Cleveland (1), Conway (3), Crawford (2), Dallas (1), Faulkner (8), Franklin (1), Garland (4), Hot Spring (1) Jefferson (5), Johnson (1), Logan (1), Lonoke (2), Miller (2), Mississippi (3), Ouachita (1), Perry (2), Phillips (1), Pike (1), Polk (1), Pope (4), Pulaski (11), Randolph (1), Saline (4), Scott (2), Sebastion (3), Sevier (1), Stone (1), Union (5), Van Buren (1), Washington (1), White (2), and Yell (2).

Copulation.--Saugey et al. (1989) observed fall copulation of red bats on two separate occasions, both of which were apparently initiated in flight. On 28 March 1993 an adult female was captured at 1920 hours in a mist net over a pool of the North Fork of the Ouachita River. Within seconds, an adult scrotal male entered the net and mounted the female. The male mounted dorsally and intermittently clenched the nape of the female's neck and upper back in his mouth maintaining some degree of tension. The male extended his legs and uropatagium around and beneath the caudal aspect of the female and attempted copulation (Fig. 2). The female remained calm during the entire episode.

Both bats were wing banded and released.

Two additional observations of red bats copulating occurred during the fall of 1997. On two occasions in September and October, high school football games were stopped while officials and coaches removed copulating red bats from the field. In both instances, bats had initiated copulation in flight and had fluttered to the ground (Coach James Sutton, Jessieville, Arkansas, pers. comm.).

Fig. 2. Copulatiing red bats

Fetuses.--There are few data regarding gender, rump-crown length or forearm lengths of fetuses due to poor condition of females submitted to ADHRL. On 19 May 1987 a female was examined that contained four very small fetuses (implanted 2L-2R) with left forearm lengths (LFA) of 6.2, 6.2, 6.4 and 6.7 millimeters [mm]. Sexes could not be determined with certainty. A female collected on 7 June 1989 contained two male fetuses. One fetus had been damaged so as to make a determination of forearm length impossible and the other had a LFA of 8 mm. On 8 June 1995, a female contained three small fetuses with LFA lengths that averaged 8.3 mm, and on 16 June 1986 a female contained four fetuses with average LFA lengths of 7 mm. Interestingly, even though all of these fetuses had similar LFA measurements, there was as much as 29 days between the dates of their collection in different years. Variance such as this suggests considerable fluctuation in dates of fertilization, parturition, lactation and postlaction from year to year and is most likely the result of environmental conditions, particularly temperature. Temperature affects the activity and availability of night flying insect prey and has a major effect upon active and dormant periods of this bat.

Saugey et al. (1988) mist-netted pregnant red bats on 16 and 23 May and 1 June in Hot Springs National Park. Caire (1986) reported the first palpable pregnancy on 22 May from the Ouachita Mountains of southeast Oklahoma, and on 18 May Gardner (1978) captured a female containing three embryos (2 males and 1 female) with average crown-rump lengths of 15 mm.

Lactation.---Fifty females were determined to have been lactating (45) or postlactating (5) at the time they were tested for rabies. Females were classified as lactating when submitted with one or more young-of-year and/or exhibited hair worn away from teats as the result of suckling by pups. Lactating females were submitted from 1 June through 16 July. Seventy-eight percent (35) of those lactating were submitted within the 19-day period between 12-30 June. The high percentage of lactating females submitted at this time may have been the result of the advanced sizes and weights of their pups and the difficulty females may have experienced in remaining attached to roost sites during inclement weather and windy conditions. Examination of Table 2 shows mean LFA lengths of pups to be 50-97 percent of

Table 2. Mean left forearm lengths for 47 juvenile red bats submitted to the ADHRL in June (1982-1996) and percent of adult male (38.7 mm) and adult female (41.1 mm) mean left forearm lengths.

DATE	SEX	LFA Range mm	Mean LFA mm	% Adult
1-Jun	Male(1)	11.6	11.6	29.9
2-Jun	Female(1)	13.8	13.8	33.5
5-Jun	Male(1)	18.2	18.2	47.0
	Female(3)	16.3-17.4	16.9	41.0
18-Jun	Male(1)	26.0	26.0	67.1
20-Jun	Male(1)	25.7	25.7	66.4
	Female(1)	31.6	31.6	76.7
21-Jun	Male(2)	28.8-29.8	29.3	75.7
	Female(5)	30.5-35.7	32.3	78.3
22-Jun	Male(2)	22.3-24.0	23.1	59.6
	Female(2)	24.7-26.3	25.5	61.9
23-Jun	Female(3)	20.8-32.9	28.1	68.2
24-Jun	Male(3)	26.0-34.8	31.3	80.8
26-Jun	Male(4)	18.8-37.8	28.4	73.3
27-Jun	Male(4)	25.6-36.7	29.7	76.7
	Female(2)	26.8-27.3	27.0	65.5
28-Jun	Male(2)	33.4-34.2	33.8	87.3
	Female(4)	34.8-39.6	36.3	88.1
29-Jun	Female(2)	38.8-39.7	39.3	95.4
30-Jun	Male(1)	39.1	39.1	100.1
	Female(2)	38.2-41.0	39.6	96.1

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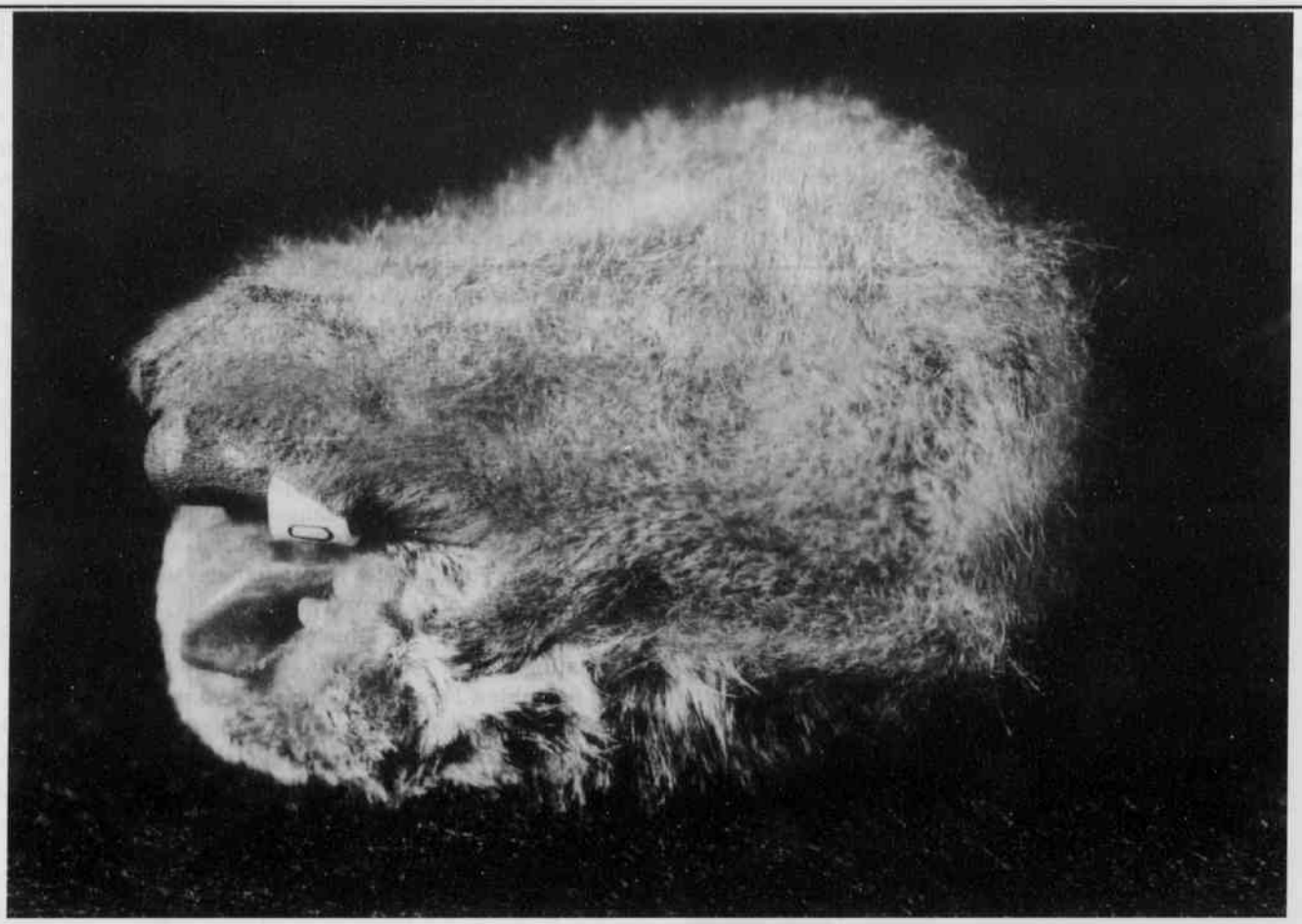

Fig. 3. Female red bat during induced hibernation. The bat is lying on her back with her uropatagium extended beyond the top of her head.

adult female mean forearm lengths during this period. In several litters, pups were observed to have forearm lengths longer than their mothers. It was also interesting to note that even though pups in many litters had forearm lengths of sufficient size to be volant, the family unit remained together.

Females were classified as postlactating when submitted without young and when they exhibited re-growth of hair around teats indicating suckling had ended prior to their collection. Postlactating females were submitted 2 July through 9 August.

Other studies have reported similar dates. In northeast Arkansas, Gardner (1978) reported lactating females on 13, 16, 23, 25 and 26 June. Saugey et al. (1988) mist-netted lactating females on 30 June, 8 and 18 July and postlactating specimens on 1 and 8 July in Hot Springs National Park. In southeast Oklahoma, Caire (1986) reported the first lactating female on 18 June, the first post-lactating female on 2 July and the last postlactating female 9 August.

Litter Size.--A total of 131 young-of-year consisting of 63 females and 68 males was examined for the months of June and July. Of this number, 98 were collected with lactating females, and the remaining 33 were collected with siblings only. These bats were contained within thirty-eight litters. Of these litters, 8 consisted of two young; 14 consisted of three young, and 10 consisted of four young. The overall ratio of males to females within these litters was 1.08:1. Litters were typically composed of a combination of male and female pups, but on several occasions litters were composed entirely of males or females. Six females were accompanied by only one young which is not considered typical litter size but which has been reported in the literature (Barbour and Davis, 1969). These single-young litters may have resulted from predation, other mishaps, or failure of the collector to secure all siblings. Left forearm lengths were noted for 47 of these pups (Table 2), but weights were not recorded. There were no lactating females, females with

young, or young without females submitted to the ADHRL during the month of May of any year. Elsewhere in Arkansas, Gardner (1978) reported one litter of 4, three litters of 3, and one litter of 2 totaling eight females, five males and two of unknown sex from northeast Arkansas. Saugey et al (1988) captured a juvenile female that had a mass of 5 g on 30 June 1982 and Caire (1986) captured the first flying young in southeast Oklahoma on 18 June.

Radiotelemetry.--Thirteen adult red bats were fitted with radiotransmitters in 1994 and 1995. Signals from 10 of these were not detected following the release date and are presumed to have flown beyond the search and study areas. In December 1993 an adult female was captured in a mist net over the North Fork of the Ouachita River. She was radiotracked to a large short-leaf pine tree where she roosted for three days and was subsequently tracked to a small shrub. The following day she was discovered hibernating in the hardwood-pine leaf litter on the forest floor. She remained at this location for at least eighteen days after which the battery on her transmitter was exhausted. During this period, daytime temperatures remained near 2.5 degrees C, substrate temperatures averaged 4.5 degrees C, and nighttime temperatures dropped near -2 degrees C or cooler. This bat was observed on a daily basis by gently removing enough leaf litter to verify that she was still alive. Interestingly, she would often be found lying in a different position, but always with her well-furred uropatagium pulled up near her neck (Fig. 3). The discovery of this female's choice of a hibernation site was not unexpected and confirmed observations by Saugey et al. (1989). In that study of bats ofthe Ouachita Mountains, red bats were observed to be "smoked" from hibernation sites during prescribed burning activities in the Ouachita National Forest. However, at the time these observations were made, a determination of whether those bats had come from tree roosts or from the leaf litter could not be made although most observers indicated they believed these bats were coming from the leaf litter. These observations made sense because at the time these prescribed burns occurred, deciduous trees had already shed their leaves. The color-match between the fur of red bats and the red and brown colors of fallen deciduous leaves provides an incredible degree of camouflage.

During April 1994, an adult male was radiotracked to a similar hibernation site beneath a large white oak tree in a hardwood-pine timber stand. The daytime temperatures during that time averaged 21 degrees C or higher, and this bat was alert when uncovered. Several minutes after being disturbed the bat flew from its hibernation site. Although many red bats were observed foraging at dusk that April, spring "greenup" or "leaf-out" of hardwood trees had not yet occurred, and the opportunity to roost among deciduous tree canopies was not yet available.

In May 1994 a male red bat was radiotagged and relocated in three different roost trees on three consecutive days before it left the study area. We recorded moves of 1.6 kilometers (km) from the capture/release site to the first roost tree with subsequent moves of 0.6 km and 0.3 km. In each instance this bat chose to roost in a midstory white oak tree (*Quercus alba*) even though large crowned, more mature white oaks and other hardwood species and shortleaf pine were available. At each location this bat roosted 6-7 m above the ground and chose roost sites approximately 0.5 m from the branch tip. Roost locations were on small branches at the leaf petiole/branch junction where the bat was well camouflaged among leaves and appeared as a somewhat "curled" leaf. Roost sites were also chosen on a side of the crown where an open, branch-free "flight gap" was available for easy departure and, presumably, easy access. The diameters breast high (DBH) of these trees were 10.7, 16 and 20.8 centimeters. All roost trees were located in mixed sawtimber/poletimber stands within red oak (*Quercus rubra*)/white oak/ hickory (*Carya* spp.)/shortleaf pine (*Pinus echinata*) upland forest types. Two locations were mid-slope on north and west facing areas, and one was located within a riparian zone approximately 60 m from a perennial stream. It is interesting to note that this male used three different roosts on three consecutive nights making him somewhat of a vagabond. Whether this behavior is typical cannot be deduced from these brief observations, but because red bats are not known to need or use structural habitat components (snags/cavity trees) other than tree canopies, they have an unlimited number of roost opportunites within the study area.

Discussion

Red bats may be the most common and widely distributed tree dwelling species in both rural and urban areas of Arkansas, yet only spotty information of their natural history is known. Assuming they are common and therefore numerous, the sheer magnitude of their impact upon the night flying insect populations of Arkansas's ecosystems must be staggering. Certainly, this important species deserves much more attention from researchers who at present are unable to even ascertain populations levels and whether the species is stable or in decline. Often referred to as a "weed species", red bats may prove to be extremely important to the health of timber and agricultural related industries of Arkansas. Studies designed to investigate their feeding habits and selection of prey should be intiated to help resolve their role in ecosystem dynamics.

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A Floristic Inventory of Three Bogs on Crowley's Ridge in Northeast Arkansas

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Abstract

A floristic inventory of vascular plant taxa of three wetlands known locally as bogs on Crowley's Ridge in Greene and Clay counties was conducted from August 1979 to July 1981. Total combined area of the three sites was 9.2 ha with a range from 2.3 ha to 4.3 ha. Overall 360 taxa representing 227 genera and 92 families were collected from the bogs and surrounding upland forest and identified. Plant taxa from bog sites ranged from 81 to 89 species with 35 species collected from all 3 bogs and 26 found in 2 of the 3 sites. Among the taxa identified, twelve are of concern in Arkansas and their occurrence is being tracked by the Arkansas Natural Heritage Program. Those include *Carex bromoides* (S2), *C. gracillima* (S1), *C. hvstericina* (S4), *C. normalis* (S?), *C. scoparia* (S 1), *C. stricta* (S1,S3), *C. swanii* (S3), *Dulichium arundinaceum* (S2,S3), *Chelone glabra* (S1), *Gentiana saponaria* (S2), *Ilex verticillata* (S2), and *Magnolia macrophylla* (S1).

Introduction

Crowley's Ridge is classified as one of the six natural divisions of Arkansas (Pell, 1983). The unconsolidated Coastal Plain sediments that form the core of Crowley's Ridge have been subsequently capped by loess, a buff to gray fine-grained silt or clay deposited by wind. West et al. (1980) reported three separate loess deposits from the Lower Mississippi Alluvial Plain on both the east and west sides of Crowley's Ridge. General vegetation of Crowley's Ridge consists of a mixed mesophytic forest type closely related to forests of the western Appalachian Mountain region and similar to the Loess Hills east of the Mississippi (Braun, 1964). The scattered distribution of wetlands characterized by *Sphagnum* mosses, shallow, acidic standing water and related plants had been noted previously on Crowley's Ridge (E. L. Richards, pers. comm.), but had not been investigated systematically prior to the work of Farris (1981) and Vanderpool (1984). A11 of these wetlands are non-glaciated with acid soil and water.

Similar wetland sites investigated in Kentucky and West Virginia (Gibson, 1970; Funk and Fuller, 1978; and Meijer et al., 1981) shared vegetative and abiotic characteristics with sites studied on Crowley's Ridge in Arkansas. Considerable overlap in species composition also characterizes sites in Arkansas and in adjacent states. Sites fitting the parameters described in these studies were identified as seeps (Funk and Fuller, 1978), bogs (Gibson, 1970), and swamp forests (Meijer et al., 1981). The term bog has been used in a number of different contexts with the most stringent usage corresponding to that by Schwintzer (1981) who characterized bogs as shallow glaciated basin peatlands with a surface carpet of mosses, chiefly *Sphagnum* species, and other acidophilous species and an aquatic environment that is ombrotrophic or very weakly minerotrophic. Given the uncertainty surrounding use of the term 'bog', an alternate wetlands classification system developed by Cowardin et al. (1979) could be used. In general the 'bogs' on Crowley's Ridge can be classified as belonging to the Palustrine system. Clay County and Glory Hole Bogs are of the Forested Wetlands Class, and Pine Hill Bog belongs to the Emergent Wetlands Class. The Palustrine system includes all vegetated wetlands traditionally identified as marsh, swamp, bog, fen and wet prairie (Cowardin et al., 1979).

Study Sites.--The three sites selected for this study are located on Crowley's Ridge in Clay and Greene counties in northeast Arkansas (Fig. 1). Clay County Bog (T20N,R6E,S 12,C) (Fig. 2A) is located in a narrow, wooded valley with three wetland areas connected by a small intermittent stream. Three distinct associations, bog, OakHickory Forest, and sand deposit, are represented at the site which comprises 2.3 ha. Glory Hole Bog (T17N,R4E,S23,NW1/4) (Fig. 2B) consists of a southern forested wetland and a northern flooded section and comprises 4.3 ha. This site contains several small springs and seeps which flow through the bog and into Sugar Creek. A large sand deposit flanks the site on the west. Pine Hill Bog (T18N,R5E,S21, NW1/4) (Fig. 2C) consists of two separate areas, quite different in character, separated by a strip of White Oak-Beech Forest. Total area of the Pine Hill Bog is approximately 2.6 ha. On the west side, the

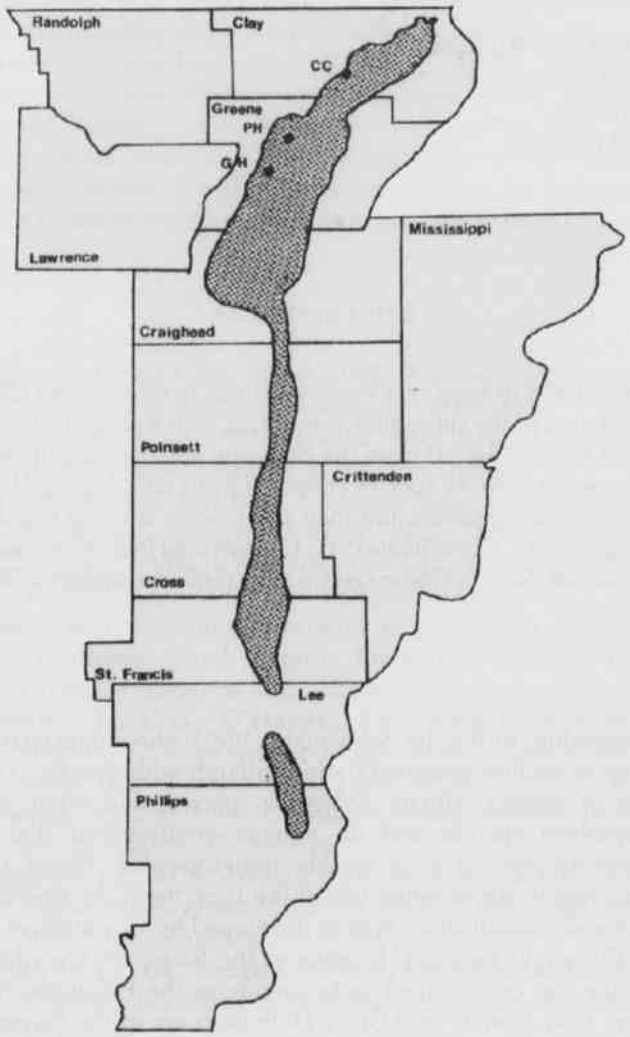

Fig. 1. Map of northeastern Arkansas showing the extent of Crowley's Ridge (shaded) and the location of study sites in Greene and Clay counties. Approximate locations of the three sites are indicated by labeled dots (CC = Clay County Bog, PH = Pine Hill Bog, and GH = Glory Hole Bog.

bog abutts on a steep sandy slope with mixed oak and pine trees in an open grassy area. The northern portion of the bog is an open sedge and rush-dominated site. The southern section is similar to the forested sections of the Clay County and Glory Hole Bogs (Vanderpool, 1984). Each of the three sites has extensive to limited mats of *Sphagnum* spp. mosses. Glory Hole Bog has extensive development of *Sphagnum* hummocks (Vanderpool, 1984).

Materials and Methods

Each study site was visited at bimonthly intervals during the growing season from August 1979 to July 1981. A complete survey of each site and the bordering upland forest was conducted with each visit. Voucher specimens were collected, pressed, dried and housed in the Arkansas State University Herbarium (STAR). Identifications were completed using taxonomic keys and/or diagnostic plates in Mackenzie (1940), Fernald (1950), Steyermark (1963), Gould (1968, 1975), and Luer (1975). Taxonomic nomenclature was updated through the use of Kartesz (1994), and Flora North America (1993, 1997).

Each study site was perimeter mapped using a Silva system type 7NL compass and a 30.5 m chain tape. An estimation of the area of each site was then made using a Lasico planimeter, #702M.

Results

A total of 360 taxa representing 352 species, 227 genera, and 92 families was collected from the bogs and surrounding upland forest and identified. Plant community of origin was noted for each specimen, and is indicated in Table I as bog (B), forest (F), or sand pit (S). The complete annotated checklist is included in Table 1 with the order of families arranged phylogenetically (Reveal, 1993). Genera and species within each family are arranged alphabetically.

Plant taxa from bog sites ranged from 81 to 89 species with 35 species collected from all 3 bogs (Table 1) and 26 found in 2 of the 3 sites (Table 1). A total of 155 taxa was collected from all three bogs, 155 from adjoining forested areas and 50 species from adjacent sand deposits. Clay County Bog was the most diverse with 259 taxa in 180 genera and 79 families. Of the total number of taxa collected, 89 were bog taxa, 130 were from the forest, and 42 were from the sand deposit. Glory Hole Bog had the second highest number with a total of 155 taxa representing 122 genera in 68 families. Species collected from the bog comprised 84 taxa with 55 collected from the forest and 16 from the adjoining sand hill. Pine Hill Bog yielded a total of 122 taxa representing 89 genera in 45 families. This total was comprised of 81 bog taxa, 37 forest taxa, and 4 sand taxa. The second largest family overall was Cyperaceae with 30 taxa in 6 genera. All 30 taxa in Cyperaceae were collected from bogs. Asteraceae was the largest family with 41 species in 28 genera with taxa occurring almost equally in forested and bog areas. Other families with strong representation included Poaceae (18 taxa), Fabaceae (15 taxa), and Orchidaceae (8 taxa).

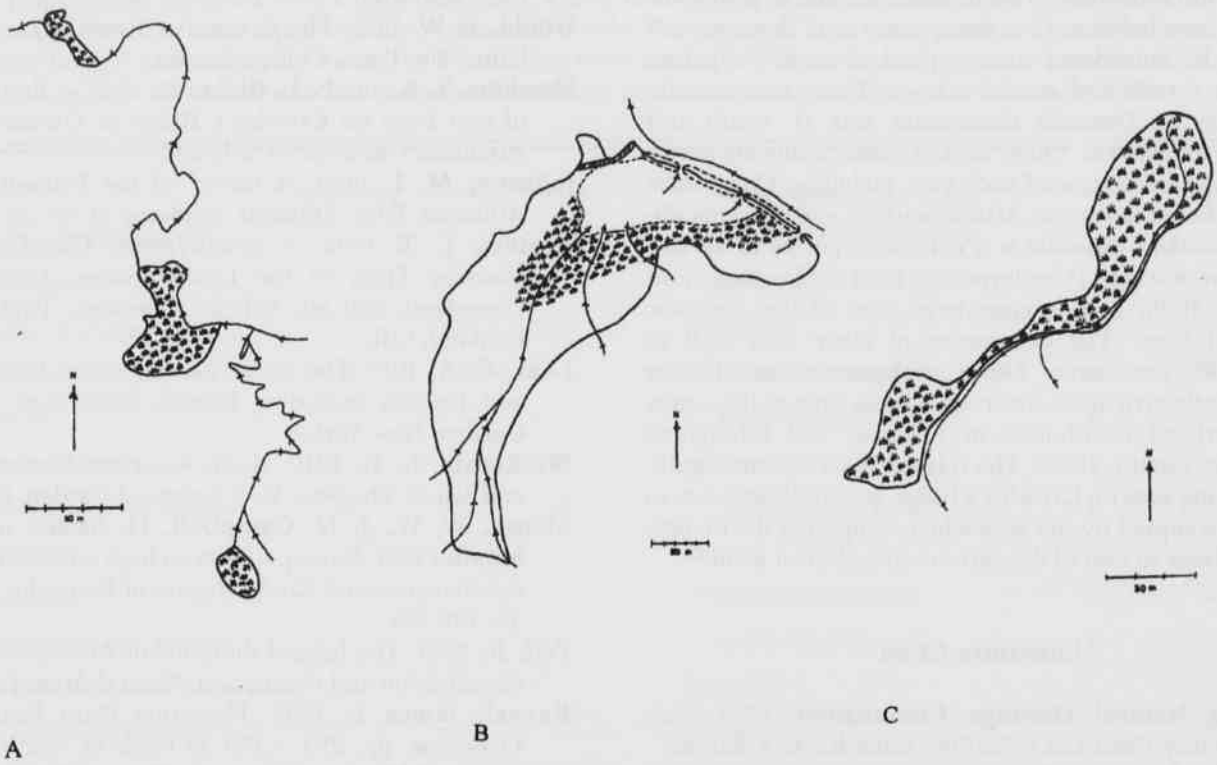

Fig. 2. Site maps of bogs investigated on Crowley's Ridge. Arrows on maps indicate direction of water flow; shaded areas represent regions with standing water and *Sphagnum* spp. mosses. A) Clay County Bog. B) Glory Hole Bog. C) Pine Hill Bog.

Discussion

All three sites studied include areas of forested bog with an overstory of *Acer rubrum*, *Liquidambar styraciflua*, and *Liriodendron tulipifera* (Table 1). Common understory woody plants include *Alnus serrulata*, *Cornus foemina*, *Corylus americana*, and *Lindera benzoin*. The substrate is densely to sporadically covered with *Sphagnum* mosses (*S. palustre*, *S. magellanicus*), ferns, sedges, and rushes. Large populations of *Triadenum walteri* and *Impatiens capensis* are also common in the ground layer.

Significance of Bogs in Northeast Arkansas.--Many of the plants collected during this study have limited distribution in Arkansas (Smith, 1988). Twelve taxa are listed presently on the Arkansas Natural Heritage Commission's State Inventory Plant List (1996). These species include eight in the sedge family [*Carex bromoides* (S2), *C. gracillima* (S1), *C. hystericina* (S4), *C. normalis* (S?), *C. scoparia* (S1), *C. stricta* (Sl,S3), *C. swanii* (S3), and *Dulichium arundinaceum* (S2,S3)]. Two herbaceous perennial species [*Chelone glabra* (S1) and *Gentiana saponaria* (S2)], and two woody species were also collected in this study [*Ilex verticillata* (S2), and *Magnolia macrophylla* (S1)]. The latter was known to be the last remaining native population in Arkansas and now is considered to be extirpated at this site.

The diversity of vascular plant species at these sites on Crowley's Ridge (Vanderpool, 1984; Hawkins and Richards, 1995) is underscored when total diversity of the 9.2 ha area investigated is compared to taxa collected from counties in the surrounding alluvial plain. Wyatt (1972) completed a floristic study of Mississippi County and identified 302 vascular plant species from the entire county. In Poinsett County, which includes a segment of Crowley's Ridge (Fig. 1), Johnson (1969) found a total of 363 vascular plant species. In this study we identified 360 taxa. Hawkins and Richards (1995) collected 262 taxa from two bogs with a total combined area of 3.6 ha.

In northeast Arkansas intense agricultural activity and development is responsible for the loss or disturbance of the native vegetation. Bog sites on Crowley's Ridge serve as a

refugium and a favorable habitat for many plants which cannot be found elsewhere. Two different groups of plants are found in these habitats. One group consists of those species that may be considered more typical of north temperate deciduous forests and northern bogs. These taxa include those such as *Osmunda cinnamomea* and *O. regalis* and *Dulichium arundinacea.* Other taxa of concern include several orchids characteristic of such sites, including *Cypripedium pubescens, Isotria verticillata, Malaxis unifolia,* and *Tipularia discolor. Platanthera clavellata* is a common species in all five bogs inventoried (Vanderpool, 1984; Hawkins and Richards, 1995) and is considered one of the indicator species of bogs. The occurrence of other taxa such as *Hymenocallis caroliniana, Lilium michiganense,* and *Chelone glabra* is indicative of the diversity of these sites, as these taxa have restricted distribution in Arkansas and throughout their range (Smith, 1988). The relative diversity and significance of bog sites on Crowley's Ridge is disproportionate to the area occupied by the sites when comparing the diversity of the bogs to that of the surrounding alluvial plain.

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Table 1. Plant species collected from Clay County Bog, Glory Hole Bog, and Pine Hill Bog, listed phylogenetically by family, with genera and species listed alphabetically within each family. The source of each species within a site is indicated by B (collected from bog), F (collected from forest), or S (collected from sandhill). The absence of any letter under a site indicates that the species was not collected at that site. An asterisk indicates taxa collected by Hawkins and Richards (1995).

TAXON	Clay County	Glory Hole	Pine Hill
DIVISION - POLYPODIOPHYTA			
Ophioglossaceae			
Botrychium dissectum Spreng.	—	B	—
Botrychium virginianum (L.) Sw.	B	—	—
Osmundaceae			
Osmunda cinnamomea L.	—	B	B
**Osmunda regalis* L. var. *spectabilis* (Willd.) Gray	B	B	B
Dennstaedtiaceae			
Pteridium aquilinum (L.) Kuhn var. *latiusculum* (Desv.) Underwood *ex* Heller	F	—	F
Pteridium aquilinum (L.) Kuhn var. *pseudocaudatum* (Clute) Heller	F	F	—
Thelypteridaceae			
Phegopteris hexagonoptera (Michx.) Fee	F	—	—
Blechnaceae			
Woodwardia areolata (L.) T. Moore	—	B	—
Aspleniaceae			
Asplenium platyneuron (L.) B. S. P.	F	F	—
Dryopteridaceae			
**Athyrium filix-femina* (L.) Roth var. *angustum* (Willd.) G. Lawson	B	B	B
Athyrium filix-femina (L.) Roth var. *asplenioides* (Michx.) Farwell	B	B	—
Onoclea sensibilis L.	B	—	—
Polystichum acrostichoides (Michx.) Schott	B	B	B
Woodsia obtusa (Spreng.) Torr.	F	—	—
DIVISION - CONIFEROPHYTA			
Pinaceae			
Pinus echinata P. Mill.	—	S	S
Cupressaceae			
Juniperus virginiana L.	S	S	—
Taxodium distichum (L.) L. C. Rich.	—	B	—
DIVISION - MAGNOLIOPHYTA			
CLASS - MAGNOLIOPSIDA			
Magnoliaceae			
**Liriodendron tulipifera* L.	B	B	B
Magnolia macrophylla Michx.	F	—	—
Annonaceae			
**Asimina triloba* (L.) Dunal	B	B	—
Lauraceae			
Lindera benzoin (L.) Blume	B	B	B
Sassafras albidum (Nutt.) Nees	F	B	F
Saururaceae			
**Saururus cernuus* L.	B	B	B
Ranunculaceae			
Anemone virginiana L.	F	—	—
Myosurus minimum L.	S	—	—
Ranunculus fascicularis Muhl. *ex* Bigel.	F	—	—
Ranunculus pusillus Poir.	F	B	—
Thalictrum dasycarpum Fisch. & Ave-Lall.	F	—	—
Berberidaceae			
**Podophyllum peltatum* L.	B	B	—
Platanaceae			
Platanus occidentalis L.	S	—	—
Hamamelidaceae			
**Liquidambar styraciflua* L.	B	B	B
Ulmaceae			
Planera aquatica J. F. Gmel.	—	B	—
Ulmus alata Michx.	F	—	—
Moraceae			
Maclura pomifera (Raf.) Schneid.	—	S	—
Morus rubra L.	F	B	—
Urticaceae			
**Boehmeria cylindrica* (L.) Sw.	B	B	B

Juglandaceae			
Carya illinoensis (Wang.) K. Koch	—	F	—
Carya ovalis (Wang.) Sarg.	F	F	F
Juglans nigra L.	—	B	—
Fagaceae			
Fagus grandifolia Ehrh.	B	—	F
Quercus alba L.	F	F	F
Quercus falcata Michx.	F	F	—
Quercus marilandica Muenchh.	—	—	F
Quercus michauxii Nutt.	—	B	—
Quercus nigra L.	F	—	—
Quercus pagoda Raf.	—	F	—
Quercus palustris Muenchh.	F	—	—
Quercus phellos L.	B	B	B
Quercus stellata Wang.	F	—	—
Quercus velutina Lam.	F	—	—
Betulaceae			
Alnus serrulata (Ait.) Willd.	—	B	—
Betula nigra L.	—	—	B
Carpinus caroliniana Walt. ssp. *caroliniana*	—	B	—
Carpinus carolinana Walt. ssp. *virginiana* (Marsh.) Furlow	—	—	B
Corylus americana Walt.	B	B	F
Ostrya virginiana (Mill.) K. Koch	B	—	—
Phytolacccaceae			
Phytolacca americana L.	—	F	—
Cactaceae			
Opuntia humifusa (Raf.) Raf.	—	S	—
Portulacaceae			
Claytonia virginica L.	F	—	F
Cryophyllaceae			
Minuartia patula (Michx.) Matt.	S	—	—
Paronychia fastigiata (Raf.) Fern.	S	—	—
Silene stellata (L.) Ait. f.	F	F	F
Polygonaceae			
Polygonum hydropiperoides Michx.	B	B	B
Polygonum pensylvanicum L.	B	B	—
Polygonum punctatum Ell.	—	—	—
Polygonum sagittatum L.	—	—	B
**Polygonum virginianum* L.	B	—	B
Rumex acetosella L.	S	S	—
Clusiaceae			
Hypericum drummondii (Grev. & Hook.) Torr. & Gray	S	—	—
**Hypericum hypericoides* (L.) Crantz ssp. *hypericoides*	—	F	—
Hypericum hypericoides (L.) Crantz ssp. *multicaule* (Michx. *ex* Willd.) Robson	F	—	F
Hypericum lobocarpum Gattinger	F	—	F
Hypericum mutilum L.	F	F	—
Hypericum prolificum L.	—	—	B
Hypericum punctatum Lam.	F	—	—
Triadenum walteri (Gmel.) Gl.	B	B	B
Malvaceae			
Hibiscus moscheutos L. ssp. *lasiocarpos* (Cav.) O. J. Blanch.	B	—	—
Cistaceae			
Lechea tenuifolia Michx.	S	—	—
Violaceae			
Viola missouriensis Greene	F	B	—
Viola palmata L. var. *dilatata* Ell.	F	—	—
Viola sororia Willd.	F	—	—
Viola viarum Pollard	F	—	—
Passifloraceae			
Passiflora incarnata L.	F	—	—
Passiflora lutea L.	B	—	—
Salicaceae			
Salix nigra Marsh.	S	B	—
Brassicaceae			
Arabidopsis thaliana (L.) Heyn.	F	—	—
Arabis lyrata L.	—	F	—
Cardamine bulbosa (Schreb. *ex.* Muhl.) B.S.P.	B	F	—
Cardamine pensylvanica Muhl. *ex* Willd.	—	B	—
Lepidium densiflorum Schrad.	F	—	—
Lepidium virginicum L.	S	S	—

Ericaceae			
Vaccinium arboreum Marsh.	F	—	—
Vaccinium pallidum Ait.	B	—	—
Monotropaceae			
Monotropa hypopithys L.	F	—	—
Monotropa uniflora L.	F	F	—
Ebenaceae			
Diospyros virginiana L.	F	F	—
Primulaceae			
Hottonia inflata Ell.	B	—	—
Lysimachia lanceolata Walt.	F	—	F
Lysimachia radicans Hook.	F	—	—
Hydrangeaceae			
Hydrangea arobrescens L.	B	—	B
Crassulaceae			
Penthorum sedoides L.	B	B	—
Saxifragaceae			
Heuchera americana L. var. *hirsuticaulis* (Wheelock) Rosend., Butt. & Lak.	F	—	—
Rosaceae			
Agrimonia rostellata Wallr.	F	—	—
Amelanchier arborea (Michx. f.) Fern.	F	—	—
Crataegus marshallii Egglest.	B	B	B
Malus angustifolia (Ait.) Michx. var. *puberula* Rehd.	S	—	—
Potentilla canadensis L.	F	—	—
Potentilla simplex Michx.	F	B	—
Prunus americana Marsh.	F	—	—
Prunus serotina Ehrh.	F	B	—
Rosa palustris Marsh.	B	—	—
Rosa setigera Michx.	F	—	—
Rubus argutus Link.	F	B	B
Rubus trivialis Michx.	B	—	—
Fabaceae			
Apios americana Medik.	B	B	B
Baptisia alba (L.) Vent. var. *macrophylla* (Larisey) Isely	S	—	—
Cercis canadensis L.	F	—	—
Clitoria mariana L.	F	F	—
Desmodium laevigatum (Nutt.) DC.	—	F	—
Desmodium nudiflorum (L.) DC.	F	—	F
Desmodium pauciflorum (Nutt.) DC.	F	—	—
Desmodium rotundifolium DC.	F	—	F
Gleditsia triacanthos L.	—	B	—
Lespedeza cuneata (Dum.-Cours.) G. Don	S	—	—
Lespedeza virginica (L.) Britt.	S	—	—
Orbexilum pedunculatum (P. Mill.) Rydb.	—	—	F
Pueraria montana (Lour.) Merr.	—	S	—
Stylosanthes biflora (L.) B. S. P.	S	—	S
Tephrosia virginiana (L.) Pers.	S	—	—
Onagraceae			
Ludwigia alternifolia L.	—	B	B
Oenothera laciniata Hill	S	S	—
Oenothera linifolia Nutt.	S	—	—
Melastomataceae			
Rhexia virginica L.	—	—	B
Cornaceae			
Cornus florida L.	F	F	F
Cornus foemina P. Mill.	B	B	B
Nyssa aquatica L.	—	B	—
Nyssa biflora Walt.	B	—	—
**Nyssa sylvatica* Marsh.	B	B	B
Santalaceae			
Comandra umbellata (L.) Nutt.	S	—	—
Celastraceae			
Celastrus scandens L.	B	—	—
Euonymus americana L.	B	—	B
Aquifoliaceae			
Ilex decidua Walt.	B	B	B
Ilex opaca Ait.	F	—	—
Ilex verticillata (L.) Gray	—	B	—
Euphorbiaceae			
Croton glandulosus L. var. *septentrionalis* Muell.-Arg.	S	—	—
Crotonopsis willdenowii G. L. Webster	S	—	—
Euphorbia corollata L.	—	S	—

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Euphorbia pubentissima Michx.	S	—	—
Vitaceae			
Parthenocissus quinquefolia (L.) Planch.	B	B	—
Vitis aestivalis Michx.	—	—	F
Vitis cineraea (Engelm.) Millard	F	F	—
Vitis rotundifolia Michx.	F	B	—
Linaceae			
Linum striatum Walt.	S	—	B
Hippocastanaceae			
Aesculus pavia L.	F	—	—
Aceraceae			
Acer rubrum L. var. *drummondii* (Hook. & Arn. *ex* Nutt.) Sarg.	—	B	—
**Acer rubrum* L. var. *rubrum*	B	—	B
Acer rubrum L. var. *trilobum* Torr & Gray *ex* K. Koch	—	—	B
Anacardiaceae			
Rhus copallina L. var. *latifolia* Engl.	S	S	—
Rhus glabra L.	S	—	—
**Toxicodendron radicans* (L.) Kuntze	F	B	B
Oxalidaceae			
Oxalis dillenii Jacq.	F	—	—
Oxalis stricta L.	F	—	—
Oxalis violacea L.	F	—	—
Geraniaceae			
Geranium carolinianum L.	F	F	—
Geranium maculatum L.	F	—	—
Balsaminaceae			
**Impatiens capensis* Meerb.	B	B	B
Araliaceae			
Aralia racemosa L.	B	—	—
**Aralia spinosa* L.	B	B	F
Apiaceae			
Cicuta maculata L.	B	—	—
Oxypolis rigidior (L.) Raf.	—	—	B
Sanicula canadensis L.	F	F	F
Thaspium trifoliatum (L.) Gray	—	—	F
Gentianaceae			
Bartonia paniculata (Michx.) Muhl.	B	B	—
Gentiana saponaria L.	B	—	—
Apocynaceae			
Apocynum cannabinum L.	S	—	—
Trachelospermum difforme (Walt.) Gray	—	F	—
Asclepiadaceae			
Cynanchum laeve (Michx.) Pers.	—	B	—
Asclepias variegata L.	F	—	F
Solanaceae			
Physalis virginiana P. Mill.	F	—	—
Solanum carolinense L.	S	—	—
Cuscutaceae			
Cuscuta compacta Juss. *ex* Choisy	—	B	B
Cuscuta cuspidata Engelm.	B	—	—
Polemoniaceae			
Phlox divaricata L.	—	F	—
Phlox glaberrima L.	F	—	—
Phlox pilosa L.	F	F	—
Boraginaceae			
Cynoglossum virginianum L.	F	—	—
Myosotis macrosperma Engelm.	—	F	—
Myosotis verna Nutt.	F	—	—
Verbenaceae			
Phyrma leptostachya L.	F	—	—
Lamiaceae			
Cunila origanoides (L.) Britt.	*F*	—	*F*
Lycopus virginicus L.	B	—	—
Mondarda fistulosa L. var. *mollis* (L.) Benth.	F	—	—
Prunella vulgaris L.	—	S	F
Pycnanthemum albescens Torr. & Gray	—	F	F
Pycnanthemum muticum (Michx.) Pers.	F	—	—
Pycnanthemum tenuifolium Schrad.	F	—	F
Salvia lyrata L.	F	—	—
Scutellaria lateriflora L.	B	B	—
Teucrium canadense L.	—	—	F
Trichostema dichotomum L.	—	S	—
Callitrichaceae			

Callitriche heterophylla Pursh	B	—	—
Plantaginaceae			
Plantago aristata Michx.	S	—	—
Plantago elongata Pursh	S	—	—
Plantago pusilla Nutt.	S	—	—
Plantago virginica L.	S	—	—
Oleaceae			
Fraxinus americana L.	F	B	—
Fraxinus profunda (Bush.) Bush	—	F	—
Scrophulariaceae			
Aureolaria grandiflora (Benth.) Pennell var. *cinerea* Pennell	F	—	—
**Chelone glabra* L.	—	B	B
Gratiola virginiana L.	B	B	—
**Mimulus alatus* Ait.	B	—	B
Nuttallanthus canadensis (L.) D. A. Sutton	S	S	—
Pedicularis canadensis L.	F	—	F
Penstemon arkansanus Pennell	F	—	—
Penstemon pallidus Small	F	—	—
Penstemon tubiflorus Nutt.	F	—	—
Veronicastrum virginicum (L.) Farw.	—	F	—
Acanthaceae			
Ruellia pedunculata Torr. *ex* Gray	F	F	—
Bignoniaceae			
Bignonia capreolata L.	F	—	—
Campsis radicans (L.) Seem. *ex* Bureau	F	—	—
Campanulaceae			
Lobelia cardinalis L.	B	—	B
Lobelia inflata L.	—	B	B
Lobelia puberula Michx. var. *mineolana* Wimm.	B	B	B
Lobelia siphilitica L.	F	F	—
Lobelia spicata Lam.	F	—	—
Triodanis perfoliata (L.) Nieuwl.	S	S	—
Rubiaceae			
Cephalanthus occidentalis L.	B	B	B
Diodia teres Walt.	S	S	—
Diodia virginiana L.	—	—	B
Galium aparine L.	—	F	—
Galium circaezans Michx.	F	—	—
Galium obtusum Bigel.	F	—	F
Galium pilosum Ait.	F	—	—
Houstonia caerulea L.	F	—	—
Houstonia longifolia Gaertn.	F	—	—
Houstonia pusilla Schoepf.	F	—	—
**Mitchella repens* L.	B	B	B
Caprifoliaceae			
Lonicera japonica Thunb.	B	B	—
Sambucus canadensis L.	B	B	—
Asteraceae			
Ageratina altissima (L.) King & H. E. Robins.	B	—	B
Antennaria plantaginifolia (L.) Richards	S	—	—
Aster ontarionis Wieg.	—	F	—
Aster patens Ait. var. *gracilis* Hook.	—	F	—
Aster pilosus Willd.	—	F	—
Bidens aristosa (Michx.) Britt.	S	—	—
Brickellia eupatorioides (L.) Shinners	—	F	—
Coreopsis tripteris L.	—	—	B
Eclipta prostrata (L.) L.	F	—	—
Elephantopus carolinianus Raeusch.	F	F	—
Erigeron annuus (L.) Pers.	B	—	—
Erigeron strigosus Muhl. *ex* Willd. var. *beyrichii* (Fisch. & C. A. Mey.) Torr. & Gray	B	—	—
Eupatorium coelestinum L.	—	—	B
Eupatorium fistulosum Barratt	B	B	B
Eupatorium perfoliatum L.	F	B	B
Eupatorium serotinum Michx.	F	—	—
Euthamia gymnospermoides Greene	B	B	—
Gnaphalium obtusifolium L.	F	F	—
Helenium amarum (Raf.) H. Rock	S	F	—
Helianthus angustifolius L.	—	—	S
Helianthus divaricatus L.	F	—	—
Helianthus microcephalus Torr. & Gray	F	—	—
Helianthus silphioides Nutt.	—	F	—
Heterotheca subaxillaris (Lam.) Britt. & Rusby	F	—	—

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Hieracium gronovii L.	F	—	—
Krigia biflora (Walt.) Blake	F	B	B
Krigia cespitosa (Raf.) Chambers	F	F	—
Lactuca canadensis L. var. *latifolia* Ktze.	—	S	—
Lactuca floridana (L.) Gaertn.	B	—	—
Leucanthemum vulgare Lam.	—	—	S
Mikania scandens (L.) Willd.	—	B	—
Parthenium integrifolium L.	—	—	F
Pluchea camphorata (L.) DC.	B	—	—
Pyrrhopappus carolinianus (Walt.) DC.	S	—	—
Rudbeckia hirta L.	F	F	—
Solidago caesia L.	F	—	F
Solidago nemoralis Ait.	S	F	F
Solidago odora Ait.	F	—	—
Solidago petiolaris Ait.	—	—	F
Vernonia gigantea (Walt.) Trel.	B	—	—
Vernonia missurica Raf.	F	—	B
CLASS - LILIOPSIDA			
Aracaeae			
Arisaema dracontium (L.) Schott	F	F	B
Xyridaceae			
Xyris jupicai L. C. Rich	—	—	B
Commelinaceae			
Commelina virginica L.	B	—	B
Juncaceae			
Juncus acuminatus Michx.	—	—	B
Juncus brachycarpus Engelm.	—	—	B
Juncus diffusissmus Buckl.	—	B	B
Juncus effusus L.	—	B	B
Juncus marginatus Rostk.	—	—	B
Luzula bulbosa (Wood) Smyth & Smyth	F	F	F
Cyperaceae			
Carex albicans Willd. *ex* Spreng.	B	—	—
Carex bromoides Schkuhr *ex* Willd.	—	B	—
Carex complanata Torr. & Hook. var. *hirsuta* (Bailey) Gl.	—	—	B
**Carex crinita* Lam. var. *brevicrinis* Fern.	B	B	B
Carex debilis Michx. var. *debilis*	B	B	—
Carex debilis Michx. var. *rudgei* Bailey	B	—	—
Carex festucacea Schkuhr *ex* Willd.	—	B	—
Carex flaccosperma Dew. var. *flaccosperma*	B	—	B
Carex flaccosperma Dew. var. *glaucodea* (Tuckerman *ex* Olney Kukenth.	B	—	—
Carex gracillima Schwein.	B	—	—
Carex hystericina Muhl. *ex* Willd.	—	—	B
Carex louisianica Bailey	B	—	—
Carex lupulina Muhl. *ex* Willd.	—	B	—
Carex lurida Wahlenb.	B	B	B
Carex normalis Mackenz.	B	—	B
Carex rosea Schkuhr *ex* Willd.	B	—	—
Carex scoparia Schkuhr *ex* Willd.	B	—	—
Carex stipata Muhl. *ex* Willd.	—	B	B
Carex stricta Lam.	—	—	B
Carex swanii (Fern.) Mackenz.	B	—	B
Carex vulpinoidea Michx.	—	B	B
Cyperus retrofractus (L.) Torr.	—	B	—
Cyperus strigosus L.	—	—	B
Dulichium arundinaceum (L.) Britt	—	—	B
Eleocharis acicularis (L.) R. & S.	B	—	—
Eleocharis tenuis (Willd.) Schultes var. *verrucosa* (Svens.) Svens	—	—	B
Rhynchospora inexpansa (Michx.) Vahl	—	—	B
Scirpus cyperinus (L.) Kunth	—	—	B
Scirpus georgianus Harper	B	—	B
Scirpus polyphyllus Vahl	—	—	B
Poaceae			
Alopecurus carolinianus Walt.	B	—	—
Andropogon virginicus L.	—	F	—
Aristida lanosa Ell.	—	F	—
Brachiaria platyphylla (Munro ex Wright) Nash	—	F	—
Chasmanthium latifolium (Michx.) Yates	B	—	—
Chasmanthium laxum (L.) Yates. var. *sessiliflorum* (Poir.) L. Clark	B	B	B
Cinna arundinacea L.	—	F	—
Dichanthelium boscii (Poir.) Gould &	F	—	B

C. A. Clark			
Dichanthelium clandestinum (L.) Gould	—	—	B
Dichanthelium dichotomum (L.) Gould	B	B	B
Dichanthelium latifolium (L.) Gould &	F	—	—
C. A. Clark			
Dichanthelium scoparium (Lam.) Gould	F	—	—
Dichanthelium sphaerocarpon (Ell.) Gould	F	—	—
Echinochloa muricata (Beauv.) Fern. var.	S	—	—
microstachya Wieg.			
Elymus virginicus L. var. *virginicus*	—	F	—
Panicum rigidulum Bosc *ex* Nees	F	—	—
Saccharum giganteum (Walt.) Pers.	—	F	—
Tripsacum dactyloides (L.) L.	S	—	—
Sparganiaceae			
Sparganium americanum Nutt.	—	B	—
Liliaceae			
Hymenocallis caroliniana (L.) Herb.	F	—	F
Lilium michiganense Farw.	B	—	—
Maianthemum racemosum (L.) Link	B	F	—
Nothoscordum bivalve (L.) Britt.	S	—	—
Polygonatum biflorum (Walt.) Ell.	F	—	F
Trillium recurvatum Beck	—	F	—
Uvularia grandiflora Sm.	F	—	—
Uvularia sessilifolia L.	F	F	—
Iridaceae			
Sisyrinchium montanum Greene	—	B	—
Smilacaceae			
Smilax glauca Walt.	B	B	—
Smilax rotundifolia L.	B	B	B
Dioscoreaceae			
Dioscorea quaternata J. F. Gmel.	F	—	B
Dioscorea villosa L.	F	—	B
Orchidaceae			
Corallorrhiza odontorhiza (Willd.) Nutt.	F	—	—
Corallorrhiza wisteriana Conrad	F	—	—
Cypripedium pubescens Willd.	F	—	—
Isotria verticillatia (Muhl. *ex* Willd.) Raf.	B	F	F
Malaxis unifolia Michx.	B	—	—
**Platanthera clavellata* (Michx.) Luer	B	B	B
Spiranthes vernalis Engelm. & Gray	F	F	—
Tipularia discolor (Pursh) Nutt.	F	—	—

Highland Pond Utilization by Bats in the Ozark National Forest, Arkansas

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Abstract

During May through August 1996, wildlife ponds (man-made and/or naturally occurring) and road ruts on the Sylamore Ranger District, Ozark National Forest, Arkansas, were mist netted to determine extent of utilization by bats. Thirty-nine ponds and road ruts were netted one or more times during 53 nights. These water sources were originally constructed to support wildlife species such as deer, turkey, etc.. This study demonstrates that taxonomically and numerically diverse bat populations use these water sources. Seven hundred and seventy bats of nine species, including two endangered species, were netted. Bats were identified, and sex, reproductive status, forearm length, and weight were recorded. All bats were banded and released at the site of capture.

Introduction

Three endangered bat taxa occur in Arkansas: Indiana bat (*Myotis sodalis*), Gray bat (*Myotis grisescens*), and Ozark big-eared bat (*Corynorhinus townsendii ingens*) (Harvey, 1975; Harvey, 1976). Studies on distribution, status, and ecology of endangered Arkansas bats have been conducted annually since 1978 (Harvey, 1978; Harvey et al., 1978; Harvey et al., 1979; Harvey, 1984; Harvey and McDaniel, 1986; Harvey and Barkley, 1990; Harvey, 1994). Although considerable information has been obtained during the past 18 years on distribution and abundance of endangered bats in Arkansas (Harvey, 1986), relatively little is known about many important aspects of their ecology, especially their summer ecology (Cope and Humphrey, 1977). Additional information concerning summer ecology of endangered Arkansas bats is essential in formulating management plans for protection and recovery of these species (Gardner et al., 1991a b).

The primary objectives of this study were to determine to what extent endangered Indiana bats remain in the vicinity of their hibernation caves during summer and to obtain information concerning their summer roosting behavior and habitat, particularly for reproductive females, if present. Approximately 3000 Indiana bats are known to hibernate in six Arkansas caves (Harvey and McDaniel, 1986). The Arkansas hibernating population has declined by 66% during the past 13 years (Harvey and McDaniel, 1986). It was previously known that a few male Indiana bats inhabit Arkansas caves during summer; however, where female Indiana bats that hibernate in Arkansas caves spend the summer was not known. Thus, this study focused on an attempt to capture Indiana bats during summer in the vicinity of known hibernation caves and to study summer roosting behavior and other aspects of Indiana bat summer ecology.

Materials and Methods

The study was conducted in the Sylamore Ranger District of the Ozark National Forest in northcentral Arkansas (Fig. 1). Two of only six known remaining Arkansas Indiana bat hibernating colonies occur in the district, and they are only a few kilometers apart. During the winter of 1995-96 these colonies contained 750 hibernating Indiana bats. Because most previous mist-netting in the area was done over flowing streams and resulted in only a few male Indiana bats being captured, it was decided to net in more upland situations, primarily over small wildlife ponds and road ruts which are the only drinking water sources available for bats along ridge tops.

Netting was conducted from 19 May through 31 August 1996. Netting was done on 53 nights at 39 sites, 33 ponds and six road ruts, for a total of 61 net nights. An attempt was made to select netting sites that were 2 km or more from streams, lakes, or other conventional water sources. Nets were set up before sunset and checked every 15 minutes until approximately 5 hours after sunset. Mist nets (3 x 6 m or 3 x 9 m) were placed across small wildlife ponds and road ruts and positioned a few inches above the water's surface.

All captured bats were retained in cloth bags until conclusion of a night's netting. Each bat was then identified,

Fig. 1. Location of the Sylamore Ranger District, a disjunct part of the Ozark National Forest in Arkansas.

sexed, reproductive condition noted, weighed, measured for forearm length, banded on a wing with a numbered plastic band, and released at the point of capture. Small 0.7 g radio transmitters were attached to 12 bats, one Indiana bat, one evening bat, and 10 northern long-eared bats. Transmitters were not used until near the end of June since they were intended for use on female Indiana bats. In the absence of female Indiana bats, transmitters were placed on other species in an attempt to learn more concerning their summer ecology.

Results and Discussion

A total of 770 bats was captured during 53 nights of netting (Table 1). Less than 2% were recaptured after their initial capture. Only six endangered Indiana bats were captured and these were all males. Thus, we confirmed that at least some male Indiana bats remain in the vicinity of their hibernation caves during summer. Failure to capture female Indiana bats suggests that reproductive females were not present in the area. However, the possibility exists that they were present but not captured. The single male Indiana bat fitted with a transmitter on 4 July was not located subsequent to release.

Other bats captured during the study included three endangered gray bats, all males. The capture of gray bats was interesting since, although summer colonies inhabit several caves in the vicinity, especially Blanchard Springs Caverns which houses a large summer bachelor colony, gray bats normally forage over larger streams and bodies of water and apparently only rarely forage on ridge tops (LaVal et al., 1977). One eastern small-footed bat (*Myotis leibii*) was netted. This species has been under review for possible listing as endangered or threatened. The species is apparently relatively rare in Arkansas and is infrequently netted (McDaniel et al., 1982).

Of major interest was the fact that 59% (455 of 770) of all bats captured were northern long-eared bats (*Myotis septentrionalis*). Previously this species was thought to be relatively rare in Arkansas (Harvey and McDaniel, 1983). Only a few are usually observed hibernating in Arkansas caves, and they are seldom netted over streams. Of 10 northern long-eared bats fitted with transmitters, most were located under the exfoliating bark of dead trees in the vicinity of their capture and release points.

ACKNOWLEDGMENTS.—Funding for this study was pro-

Table 1. Bat species captured in the Sylamore Ranger District, Ozark National Forest, Arkansas from 19 May through 31 August 1996.

	Male	Female	Total
Myotis septentrionalis	209	246	455
Myotis sodalis	6		6
Myotis grisescens	3		3
Myotis leibii	1		1
Nycticeius humeralis	24	17	41
Pipistrellus subflavus	93	3	96
Eptesicus fuscus	4	2	6
Lasiurus borealis	64	96	160
Lasiurus cinereus	2		2
Total	406	364	770

vided by the U.S. Fish and Wildlife Service through the Arkansas Game and Fish Commission from appropriations made available through Section 6 of the Endangered Species Act of 1973 (PL93-205) and a Challenge Cost Share Agreement between the U.S. Forest Service, Ozark - St. Francis National Forests and the Center for the Management, Utilization, and Protection of Water Resources at Tennessee Technological University.

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Telemetric Observations of Foraging Ozark Big-Eared Bats in Arkansas

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Abstract

Ozark big-eared bat (*Corynorhinus townsendii ingens*) foraging activities were studied during 1995 in Marion County, Arkansas. Adult bats were equipped with radiotransmitters and tracked during June and July. Foraging activities were generally within 1 kilometer (km) of the roost cave. Male bats ranged farther than females with the exception of one female that flew 2.5 km into a different watershed. Male big-eared bats and northern long-eared bats (*Myotis septentrionalis*) were also found within the maternity colony.

Introduction

Ozark big-eared bats (*Corynorhinus townsendii ingens*) once occurred across the Ozark Plateau of northern Arkansas, southern Missouri, and eastern Oklahoma (Kunz and Martin, 1982; U.S. Fish and Wildlife Service, 1995). Surveys of caves previously occupied in Missouri produced no evidence of recent use by big-eared bats during the late 1980's. Populations in Arkansas have decreased, and searches for new roosts during 1988 proved unsuccessful (Harvey and Barkley, 1990). Ozark big-eared bats use numerous caves in eastern Oklahoma, but only five caves are used extensively (Clark et al., 1993). The remaining populations in Arkansas and Oklahoma are estimated to number from 1,600 to 2,300 individuals (U.S. Fish and Wildlife Service, 1995).

Throughout their lives Ozark big-eared bats are dependent on limestone caves. Although males and females hibernate together in caves during winter, in summer females choose/select different caves where they form maternity colonies, give birth, and rear pups. Males apparently lead a solitary existence roosting in caves other than those used for maternity roosts (Clark et al., 1993; Harvey and Barkley, 1990).

Clark et al. (1993) investigated temporal changes in foraging activities by lactating adult female Ozark big-eared bats in Oklahoma. We investigated foraging activities of male and female Ozark big-eared bats with respect to habitat use and distance from cave to foraging sites. Our study demonstrates the relevance of the findings by Clark et al. (1993) to the easternmost populations of Ozark big-eared bats. Further, we note the presence of adult male Ozark big-eared bats and Northern longeared bats (*Myotis septentrionalis*) in a maternity colony.

Methods

This study was conducted in Marion County, Arkansas (Fig. 1). Two physiographic areas of the Ozark Highland province dominate Marion County. The Salem Plateau is exposed across the north and east, and the Springfield Plateau is exposed in parts of the west central and across most of the southern part of the county. The Salem Plateau is characterized by gently sloping to rolling uplands and steep, stony, side-slopes. Elevations range from 200 to 300 meters (m). The Springfield Plateau is adjacent to and higher than the Salem Plateau. Elevations atop the ridges in the Springfield Plateau range from 300 to 400 m. This plateau has been strongly dissected by streams and is characterized by steep, v-shaped valleys separated by gently sloping to moderately sloping, narrow ridges. Our study site was located along the interface of the two plateaus, but was more characteristic of the Springfield Plateau.

The study area was located on the watershed of Jimmie Creek, a low-order spring-fed stream. Oak-hickory forests dominate the area, which at one time had been cleared for cattle and crop production. The forest is open with little or no undergrowth. Dense vegetation occurs within and 4-6 m upslope of Jimmie Creek. Reed cave is located in a box canyon running north and south (Fig. 2) with a small waterfall (3-5 m) at the northern end. The cave is located on the east side of the canyon and has two entrances. The larger entrance is located near the north end, whereas a smaller entrance is located 10-12 m to the south or downstream. This tributary of Jimmy Creek is intermittent, flowing only after substantial rain.

Forty-four Ozark big-eared bats were captured during June and July 1995 with a large hoop net inside Reed cave. Seven females and five males were banded with numbered plastic bands, and sex, body mass (g), and left forearm lengths were recorded (Table 1). Bats having a mass less

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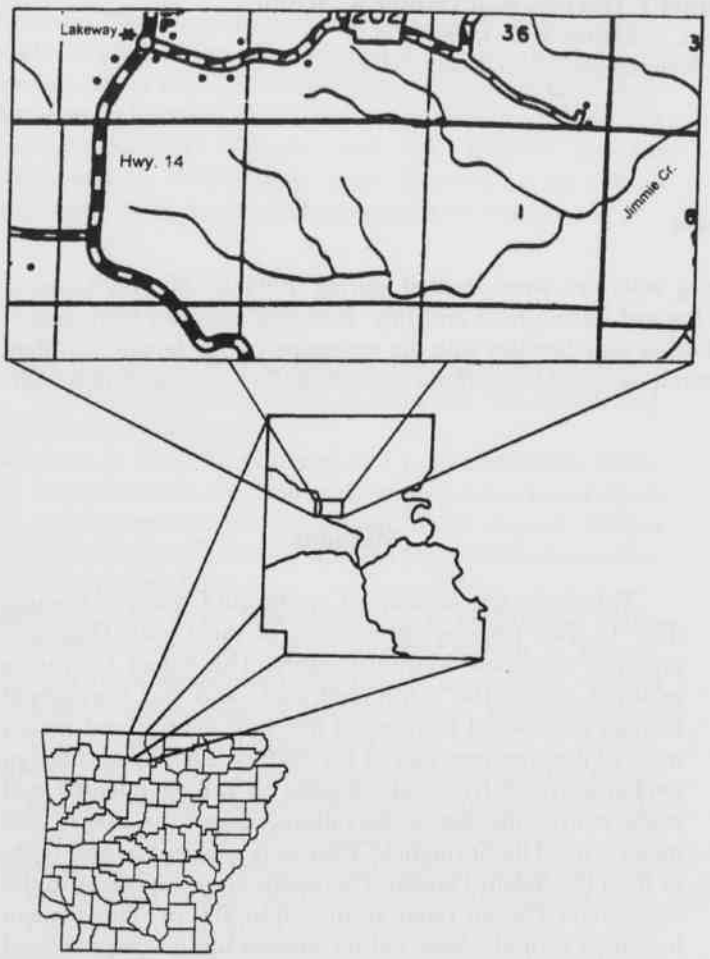

Fig. 1. Upper Jimmie Creek watershed, Marion County, Arkansas

than 10g were not radio-tagged because they probably represented juvenile, unskilled flyers and not established foragers. One of two types of radio-transmitters, (0.67g model DB-2Brd or a 0.51g model LB-2rd, Holohil Systems Ltd., Ontario, Canada) was attached directly to the pelage of bats with surgical glue (Skin Bond). When released, bats appeared to have no diffficulty flying with the added weight of the transmitters. These small transmitters had a signal range of 1 km and a battery life of 2-3 weeks. Bats were tracked simultaneously from two stationary locations with receivers (Model TRX-1000s and Falcon Five w/Model APS-164 SCAT Scanner, Wildlife Materials, Carbondale, IL). Radio-synchronized bearings were taken at 15-30 minute intervals. Most observations were made between sunset and 0100 hrs CST. Triangulation was not possible with only two receivers, so gain and signal strength were noted. Occasionally due to an individual bats close proximity (high signal strength), it would be monitored continuously for 5-10 minutes to provide micro-details of foraging. All recorded locations and times were plotted on 7.5 minute United States Geological Survey quadrangle maps.

Results and Discussion

Twelve adult Ozark big-eared bats were radio-tracked during June and July 1995. Typically bats begin flying 30-45 minutes prior to sunset, during which time they usually fly out of the cave, circle, and return. This activity has been precisely documented and attributed to light sampling (Twente, 1955). Males were present within the colony early in the maternal period, but their numbers dwindled as the summer progressed. Male Northern long-eared bats (*Myotis septentrionalis*) were also present in small numbers (<10) within the colony throughout the summer. Adult female Ozark big-eared bats remained in the colony through lactation, but as the young became volant, the number of these adult females also decreased.

Edge habitat has been demonstrated as the preferred foraging sites for Ozark big-eared bats as it may provide cover for both bats and moths, the bats primary prey (Clark, 1991). Open forest situations allow easy feeding because bats are able to discriminate insects at greater distances; however, open habitats provide little structural protection from predators (Erkert, 1982). The area along Jimmie Creek provides horizontal edge habitat along the creek itself and vertical edge habitat along the side of the valley. Although dense undergrowth occurs along the bottom of the valley near the creek, the forest is generally open under the canopy.

All radio-tagged bats remained within the area of the roost (< 1 sq. km) with the exception of one female (#1610) which flew 2 km to an adjacent watershed containing Blue Heaven Cave, another known maternity site (Fig. 2). Within the Jimmie Creek watershed, males foraged farther from the cave than did females. One male was observed to forage progressively farther from the cave over the three consecutive nights it was tracked. All adults began foraging activity near the cave, later moving farther away, but never leaving the Jimmie Creek watershed.

Preservation of these and other endangered cave bats should focus on protection of caves and management of surrounding foraging areas (Harvey and Barkley, 1990; White and Seginak, 1987; Harvey and McDaniel, 1986). Clark et al. (1993) stated that female Ozark big-eared bats foraged at progressively greater distances from the roost cave during the lactation period. We did not find this to be the case in the Jimmie Creek area. This study reveals that the area actually used by this population of Ozark big-eared bats appears to be rather small (1-2 km^2.).

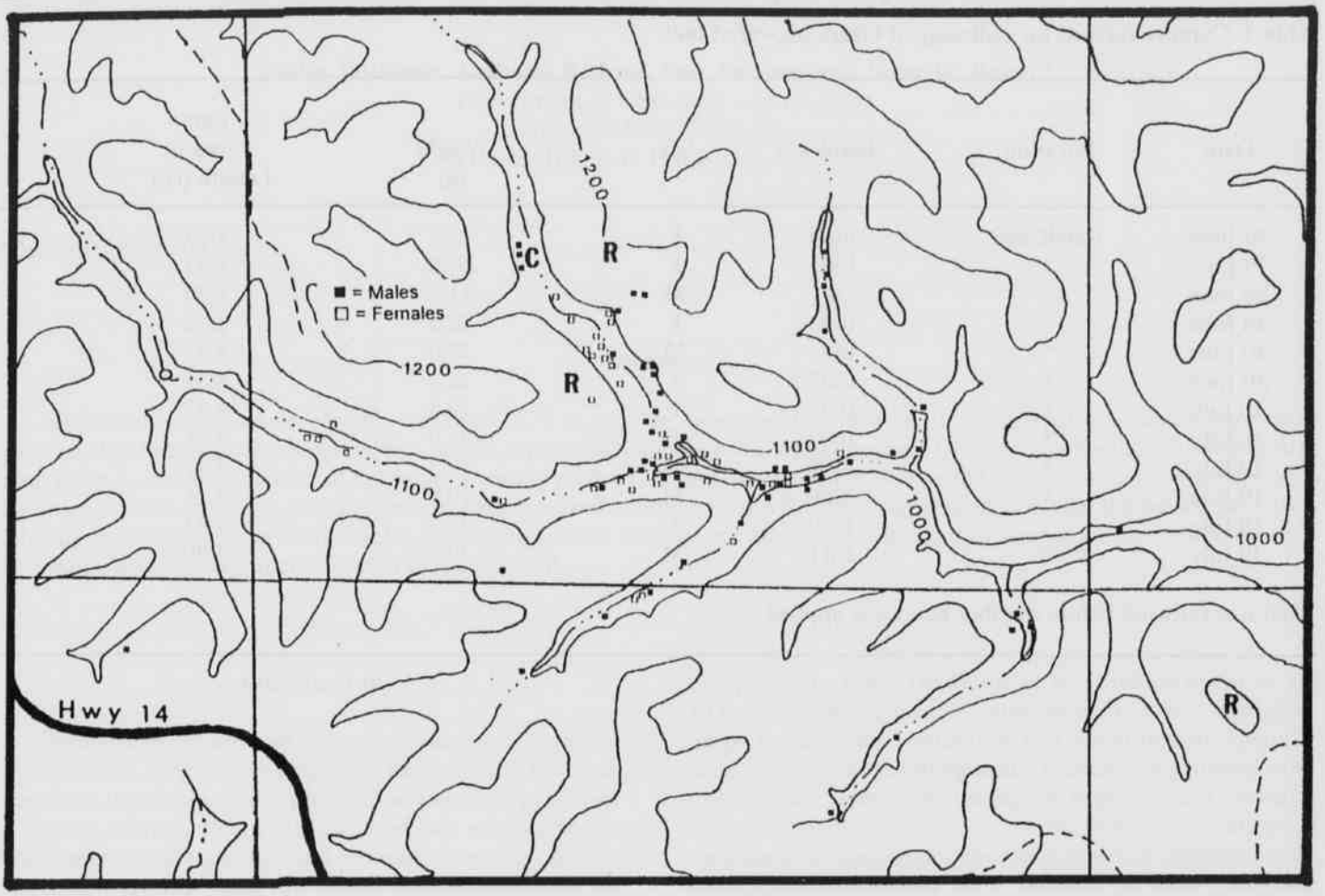

Fig. 2. Foraging activity of Ozark big-eared bats along Jimmie Creek, Marion Co., Arkansas (T19N, R17W, Sec 2.).
C = Cave R = Receiver locations

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Table 1. Capture records for radiotagged Ozark big-eared bats.

Date	Location	Band #	Sex	Weight (g)	Left Forearm Length (cm)
19 June	ReedCave	1600	F	13.5	4.55
19 June	"	1601	F	12.02	4.33
20 June	"	♦	M	11.5	4.46
20 June	"	1603	F	12.5	4.62
20 June	"	1604	M	12.0	4.37
20 June	"	1605	F	12.5	4.35
16 July	"	1606	F	12.5	4.37
16 July	"	1607	F	14.0	4.51
19 July	"	1608	M	10.5	4.47
19 July	"	1609	M	10.0	4.41
19 July	"	1610	F	12.5	4.54
19 July	"	1611	M	10.5	4.39

♦bat was released before number band was applied.

Using LabVIEW to Synchronize an Infrared Diode Laser Spectrometer with a Pulsed Supersonic Jet Expansion

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Abstract

We describe software developed with LabVIEW to provide operational control for an *in-house* infrared diode laser spectrometer that has been combined with a pulsed supersonic jet expansion sample source. Data were collected with this instrument using a modified version of the rapid-scanning method. A prerequisite in employing the rapid-scan detection scheme is that the modulation used to scan the laser be synchronized in time with the electrical signal used to trigger the pulsed gas valve. Software performance was evaluated by examining a series of rotation vibration (ro-vibrational) spectra for the carbon monoxide molecule in the five micron region of the infrared.

Introduction

High resolution infrared laser spectroscopy is a proven experimental method for obtaining fundamental information about the chemical and physical properties of gas phase molecules (Hirota, 1992). Tunable lead salt semiconductor diode lasers are frequently used to make these high resolution measurements. Lead salt diodes are manufactured for the entire 3-30 micron region of the infrared and possess a narrow spectral width output which permits the resolution and measurement of rotational fine structure. Complete infrared diode laser spectrometers are available commercially, although these complete systems are quite expensive (~$50,000 for a liquid nitrogen cooled system). Over the last year, we have assembled an *in-house* infrared diode laser spectrometer from individual spectrometer components that can be purchased separately for approximately half the price of a complete commercially assembled system. In addition to the spectrometer, we have also constructed a supersonic jet expansion vacuum system from commercially available components. The combination of a supersonic jet sample source and an infrared diode laser spectrometer to perform direct absorption infrared measurements was first described about twenty years ago (Gough et al., 1978). Since that time, this instrumental combination has been used to investigate the properties of several stable gas phase molecules (see for example, Takami et al., 1988; Davies et al., 1990; Burie et al., 1991; Gang et al., 1992; Brown et al., 1993; and Davies et al., 1994), as well as weakly bound species such as van der Waals complexes (see for example, Sharpe et al., 1988; De Piante et al., 1989; Schuder et al., 1991; McKellar et; al., 1992; and Hu et al., 1993). One challenge faced when combining two sophisticated scientific instruments is establishing and executing operational control for each instrument during an experiment. Operation and control for our infrared diode laser spectrometer, a supersonic jet expansion, and the peripheral detection electronics is accomplished via a Pentium personal computer (PC) equipped with the LabVIEW full development software package. LabVIEW is a graphical programming language commercially available through National Instruments. Following De Piante, Campbell, and Buelow (1989), we have optimized the software to increase instrument sensitivity and resolution and decrease laser source noise. In a companion paper submitted to these proceedings, we provide a detailed description of the instrument assembled at Arkansas State University. Here, we describe the development and optimization of a LabVIEW algorithm designed to control and operate the spectrometer.

Materials and Methods

A schematic of our *in-house* infrared diode laser spectrometer is shown in Fig. 1. Experiments are performed by collimating infrared radiation from one of three Pb-salt diodes with an off-axis parabolic mirror (OAPM) and focusing the light with a 250 millimeter (mm) CaF_2 lens into a 0.5 meter monochromator for mode selection. Upon exiting the monochromator, the beam is collimated with a second 250

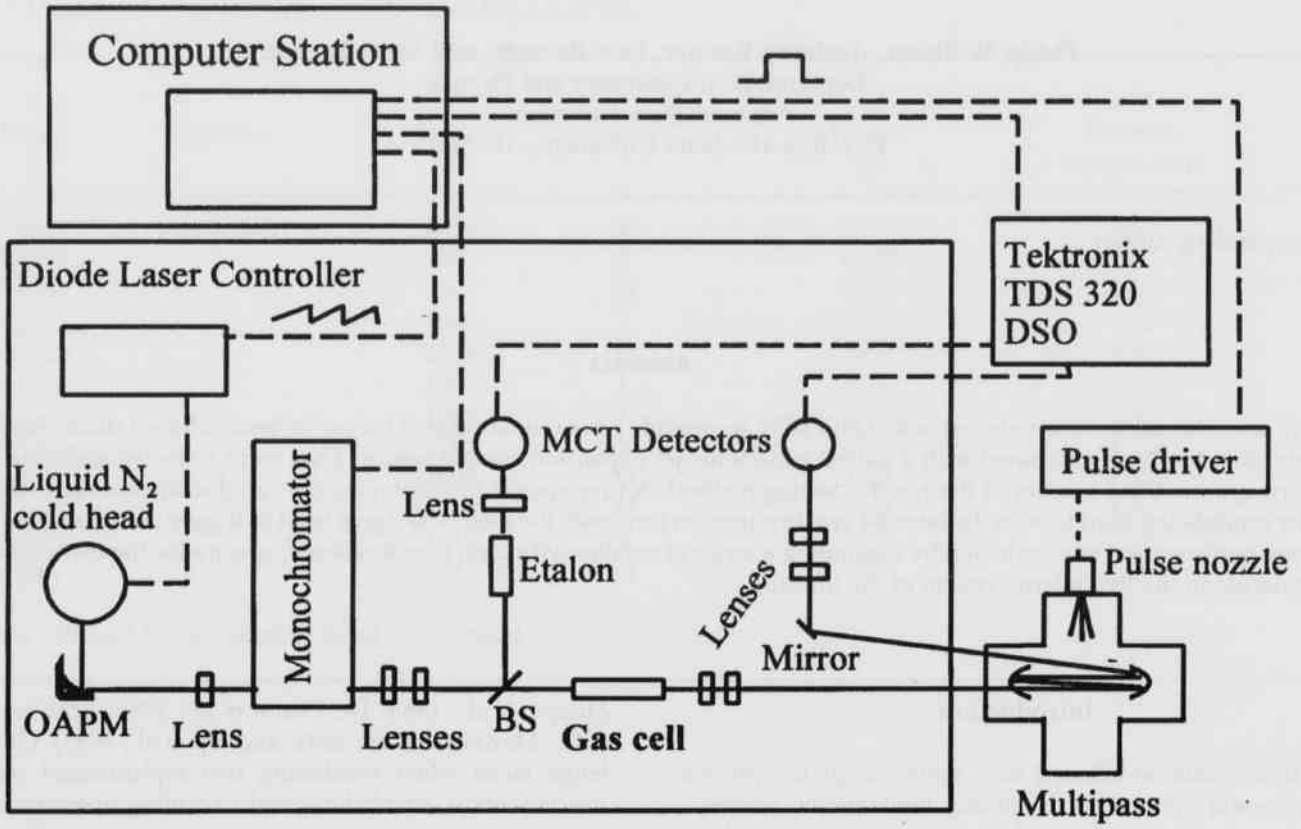

Fig. 1. Tunable diode laser spectrometer. The solid line represents the optical path and the dotted line shows the electrical connections.

mm CaF_2 lens before intersecting a beamsplitter positioned to send 8% of the radiation through a tuning rate etalon for calibration. The remaining 92% first traverses the length of a reference gas cell before being focused into a multipass mirror arrangement inside the chamber where it will make 15-30 passes through a pulsed jet expansion about 1 cm downstream of the nozzle. The signal channel is finally focused with a CaF_2 f/2 lens onto a mercury cadmium telluride (MCT) infrared detector. MCT detectors produce a voltage that is proportional to the incident infrared radiation. This voltage is first amplified and filtered with an voltage amplifier before being displayed on a digital storage oscilloscope.

Pb-salt diode lasers can be specified to provide coverage of an approximately 150-200 wavenumber (cm^{-1}) window within the 300-3500 cm^{-1} spectral region. Individual diode lasers can be tuned or scanned through this ~200 cm^{-1} window by controlling the diode temperature and applied current. The nominal operating range for a Pb-salt diode is 80-140 Kelvin (K). Coarse tuning is accomplished through changes in the diode temperature. As an example, we have tuned one of our diodes from 1870 cm^{-1} to 2015 cm^{-1} by varying the temperature from 83 K to 116 K. Fine tuning of the laser is done with the applied current. A nominal tuning rate for each of our diodes is ~0.04 cm^{-1} per milliamp (mA). High resolution scans for a given region are obtained by setting the temperature to an appropriate value and varying the current. We have opted to use a modified version of the rapid-scan method for data collection rather than the conventional slowscan boxcar based method. Originally described by De Piante and coworkers (De Piante et al., 1989), the rapid-scan method involves scanning the diode laser by applying an external modulation in the form of a voltage ramp to the diode laser controller. Here we apply a 0-5 volt (V) ramp at a frequency of 25-85 Hertz (Hz) with a step size of 5 millivolt (mV). The laser controller converts the applied voltage into a current applied to the diode. A modulation depth of 5 V corresponds to the current being scanned through a 100 mA region 50 mA on either side of some preset value, with a step size of 90 microamp (μA). To

put this into more familiar spectroscopic terms, a 100 mA change corresponds to a scan through 4 cm^{-1} with a step size of less than 0.003 cm^{-1}. Unfortunately, diode lasers do not produce continuous radiation, but rather lase on several longitudinal modes for a given temperature and current setting. The longitudinal modes are typically 1-2 cm^{-1} in length and separated from one another by several wavenumbers. Thus, a scan of 100 mA represents a scan through one of these longitudinal modes. With a repetition rate of 25 Hz, the scan is completed in 40 milliseconds (ms) yielding a scan rate of ~0.1 cm^{-1}/ms. The primary advantage to the rapid scan technique is sensitivity. Absorption features with a full width at half maximum of 0.006 cm^{-1}, for example, are effectively modulated at electronic frequencies of 20 kilohertz (kHz). Source noise, laser 1/f noise, and noise from other sources generally occur at much lower frequencies. Thus, the noise can be electronically filtered before the absorption signal is recorded. Using the rapid-scan method, De Piante et al. (1989) have reported absorption measurements near the shot noise limit.

The sample source for this experiment is a pulsed supersonic jet gas expansion. The expansion is housed in a vacuum chamber that is evacuated with a six inch diffusion pump backed by a mechanical pump. The pumping throughput of this system is ~1200 liters/second with a liquid nitrogen cryotrap. Under load, the pumping system is able to maintain a chamber pressure of $< 5 \times 10^{-4}$ Torr. The jet expansion itself is created with a General Valve series 9 pulsed valve combined with a matched pulse valve driver. The pulse driver has a great deal of experimental flexibility in the sense that the valve can be opened and closed at repetition rates of 1 to 250 Hz. Duration or length of a gas pulse can be varied from 1 microsecond (μs) to 100 ms. Control for the pulse driver, and thus the pulse valve, is provided by sending a 5 V pulse to the driver. The length of time the nozzle remains open during an experiment is determined by the time duration of the 5 V pulse. For a molecular absorption to be observed, the gas pulse and laser voltage ramp must have the same repetition rate and be synchronized in time. The necessary synchronization is obtained via a Pentium 100 MHz PC equipped with a general purpose interface bus (GPIB) card, an eight channel-12 bit data acquisition card (DAQ), and the LabVIEW full development software package.

Results and Discussion

Analog electrical signals for the voltage ramp and the voltage pulse are generated as arrays in a LabVIEW virtual instrument (VI) or algorithm. Synchronization is accomplished by binding the two one-dimensional arrays together. The LabVIEW package comes complete with a large number of VI's to help minimize software development time. We have utilized many of these *built-in* VI's including a ramp generation VI, GPIB talk/listen VI's, serial read/write VI's, as well as VI's designed to configure and write analog electrical signals to the analog output ports on a DAQ card installed in the Pentium PC.

In addition to tuning the laser, the voltage ramp is also used to trigger a digital storage oscilloscope during data collection. Transient absorption waveforms are acquired on the oscilloscope and transferred to the Pentium PC via an IEEE 488 (GPIB) bus. An example of a single transient absorption obtained with our instrument is shown in Fig. 2. Both waveforms in Fig. 2 show a sequence of five laser ramps. The bottom trace represents a typical etalon spectrum. An etalon signal is recorded simultaneously with the signal channel and is used for calibration. Here a one inch solid piece of germanium etalon produces maxima spaced by 0.048 cm^{-1}. The top trace in Fig. 2 is the signal channel. The three apparent steps on each ramp correspond to three different laser modes (the monochromator in this case was set to pass all wavelengths). On the laser mode farthest to the right, two molecular absorptions are clearly seen. These two absorptions were obtained with a 10 cm gas cell containing reagent grade carbon monoxide at a pressure of ~2 Torr. Carbon monoxide was chosen as a test molecule during the software optimization phase of work because it has been extensively studied. In fact, a complete listing of every known carbon monoxide absorption in the five micron region can be downloaded from the National Institute of Standards and Technology website, viz http://physics.nist.gov. The molecular absorptions in Fig. 2 represent rotationally resolved vibrational transitions for two different isotopic forms of carbon monoxide.

Of course, a major objective in developing the LabVIEW software was to interface a supersonic jet expansion sample source with a tunable diode laser spectrometer. One of the experimental challenges, even with pulsed jet expansions, involves trying to deal with gas flows that can exceed the available pumping capacity. The major difference between our spectrometer and the instruments described by De Piante et al., and others (De Piante et al., 1989; Schuder et al., 1991; McKellar et al., 1992; Hu et al., 1993; Low et al., 1996) is how this problem of limited pumping capability is handled. The LabVIEW software described above allows us to vary the voltage ramp repetition rate from 1-100 Hz. A voltage ramp of 0-5 V with a step size of 5 mV and a repetition rate of 25 Hz will have a period of 40 ms. The gas pulse must of course be synchronized with the voltage ramp; however, a gas pulse of 40 ms would simply raise the background pressure in the expansion chamber to unacceptable levels. In fact, a realistic length for a gas pulse is on the order of 0.5-1.5 ms depending on the backing pressure of the gas in the reservoir. In other words, our pumping system requires that the gas pulse be shorter than

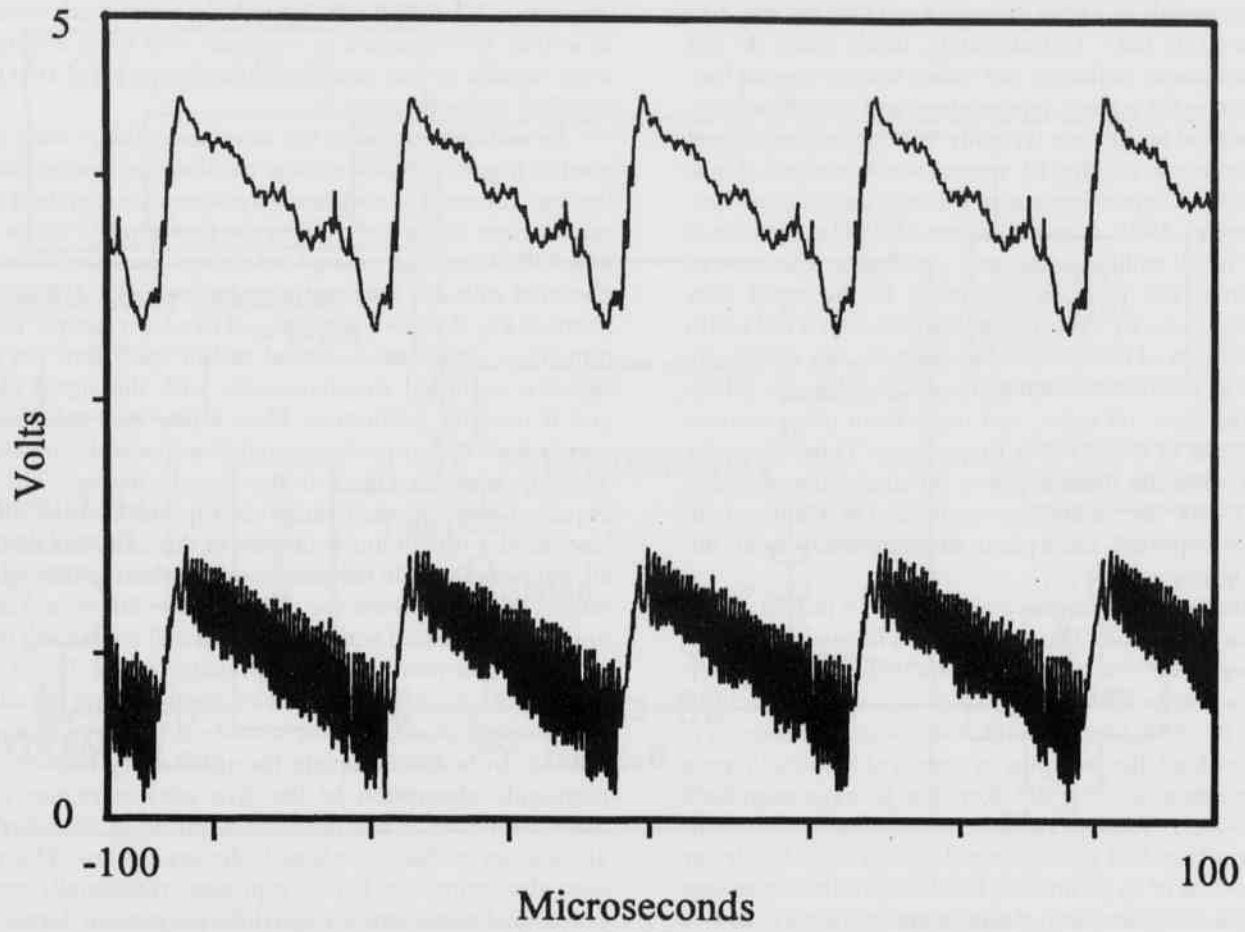

Fig. 2. Single transient absorption waveform collected with the infrared diode laser spectrometer at Arkansas State University. Five laser lamps are shown for the signal channel (top trace) and the etalon calibration channel (bottom trace).

the voltage ramp, even at higher frequencies (e.g., a 100 Hz rep rate shortens the ramp period to 10 ms). To deal with this issue, the software has been developed with the flexibility to allow the gas pulse to be positioned anywhere along the voltage ramp. Figure 3 provides a pictorial description of this idea. The top trace in Fig. 3 was obtained using a gas mixture consisting of 30 % reagent grade carbon monoxide in argon, and the two absorption features correspond to two different isotopic species of carbon monoxide, $^{12}C^{16}O$ and $^{12}C^{18}O$, respectively. The peak to the left is P(11) for the v = 0→1 band of $^{12}C^{16}O$. The smaller peak is R(1) for the v = 0→1 band of $^{12}C^{18}O$. Rotationally resolved spectra such as those shown in Fig. 3 are generated by the coaddition, in real time, of transient absorption waveforms over many gas pulses. For the spectrum in Fig. 3, 500 waveforms were averaged and a background subtraction performed before the data were recorded. The bottom half of Fig. 3 illustrates the relationship between the gas pulse, the voltage ramp, and the frequency of the infrared radiation. For this particular spectrum, the gas pulse was positioned on the ramp to optimize the intensity of the $^{12}C^{18}O$ peak. The larger line from the $^{12}C^{16}O$ species is visible under non-optimized gas pulse conditions because it is a strong line. If we had recorded the spectrum with the gas pulse optimized on the more intense feature, the smaller peak would not be observed.

To cover a particular infrared region then, several spectra, differing only in the gas pulse position along the ramp, must be recorded. For example, a series of three spectra for the same ~1 cm^{-1} region in the infrared (2099.0827-2100.1366 cm^{-1}), acquired at different gas pulse positions along the voltage ramp, are displayed in Fig. 4. The three lines in Fig. 4 represent rovibrational transitions for the v = 0 → 1 band of three different isotopic species of carbon monoxide. The P(11) line of $^{12}C^{16}O$, the most abundant iso-

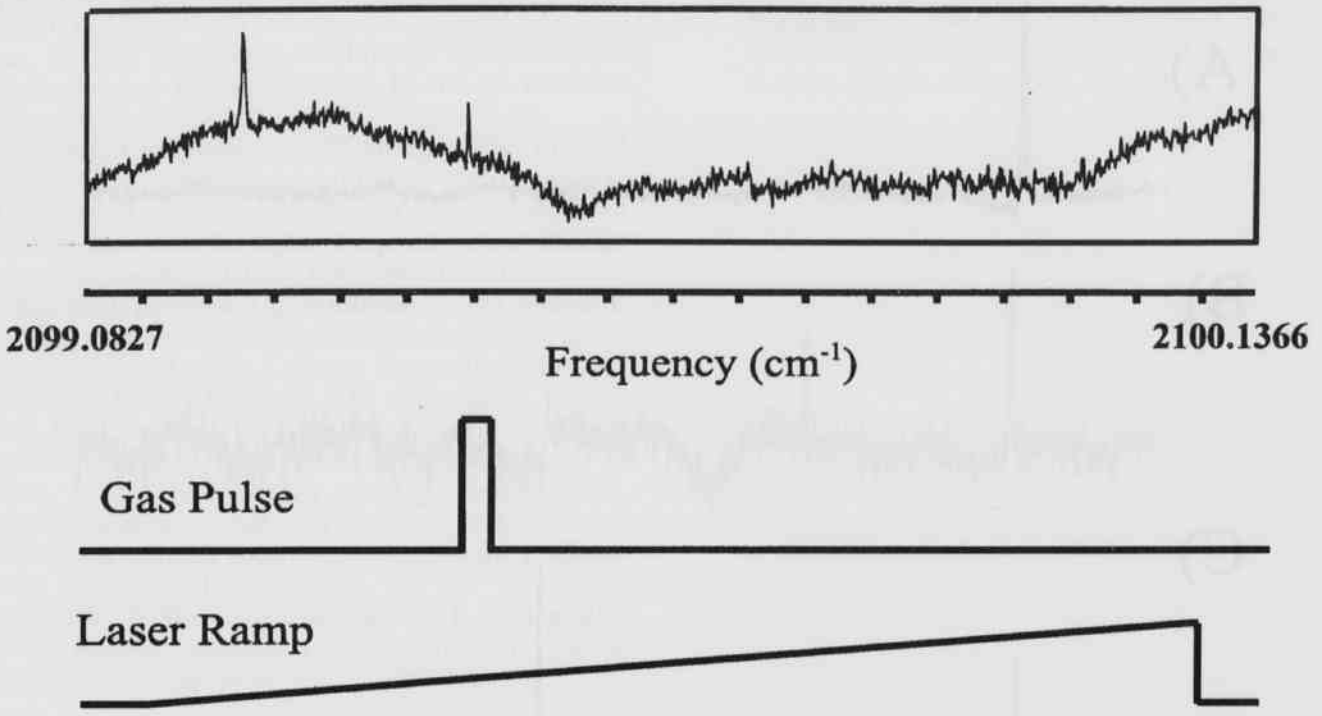

Fig. 3. Relationship between gas pulse, laser ramp, and observed spectra.

topic species of carbon monoxide, is shown in Fig. 4a. Figure 4b is another view of the spectral region shown in Fig. 3 and the line assignments are described in the text above. Finally, in Fig. 4c, the R(0) line of $^{13}C^{16}O$ is observed at 2099.7101 cm^{-1}. The gas pulse in Fig. 4c was positioned to optimize the intensity of the $^{13}C^{16}O$ transition.

Each of these individual spectra is saved in spreadsheet form complete with a header containing all the information for the scan, e.g., laser current, laser temperature, oscilloscope settings, pulse duration, pulse position along the voltage ramp, voltage ramp repetition frequency, and voltage ramp period, which is automatically recorded by the scanning program before the file is saved. Because the spectra are saved in spreadsheet form, a *complete* spectrum, containing all the molecular absorptions in a particular infrared region, can be obtained by simply summing the individual files together. We have performed this spreadsheet summation manually with the three spectra shown in Fig. 4. Thus, the complete absorption spectrum for carbon monoxide in the 2099.0827 - 2100.1366 cm^{-1} region of the infrared appears in Fig. 5. Generally speaking, the spreadsheet summation for a molecule with a previously unobserved rotationally resolved vibrational spectra will normally include more than three individual files. Consider the following experimental situation. A voltage ramp with a 25 Hz repetition rate will have a 40 ms period. If a 1 ms gas pulse length is used, 40 experiments will need to be performed, each with an incrementally different gas pulse position along the laser ramp, to completely cover an infrared region with a single longitudinal lasing mode. The acquisition time at a single gas pulse position is about four minutes. The total scan time to cover a ~1-2 cm^{-1} region then, is approximately 2 1/2 hours. Keep in mind, however, a 0.003 cm^{-1} instrumental resolution (determined from the step size of the voltage ramp) will allow us to make rotationally resolved vibrational measurements for a large number of gas phase molecular systems. In other on-going research, we are attempting to obtain high resolution infrared spectra for several transition metal carbonyl compounds. These compounds are particularly challenging to study in a jet as most are solids at room temperature. In a companion paper, we also describe efforts to entrain the vapor pressure above a solid and inject it into a supersonic jet expansion.

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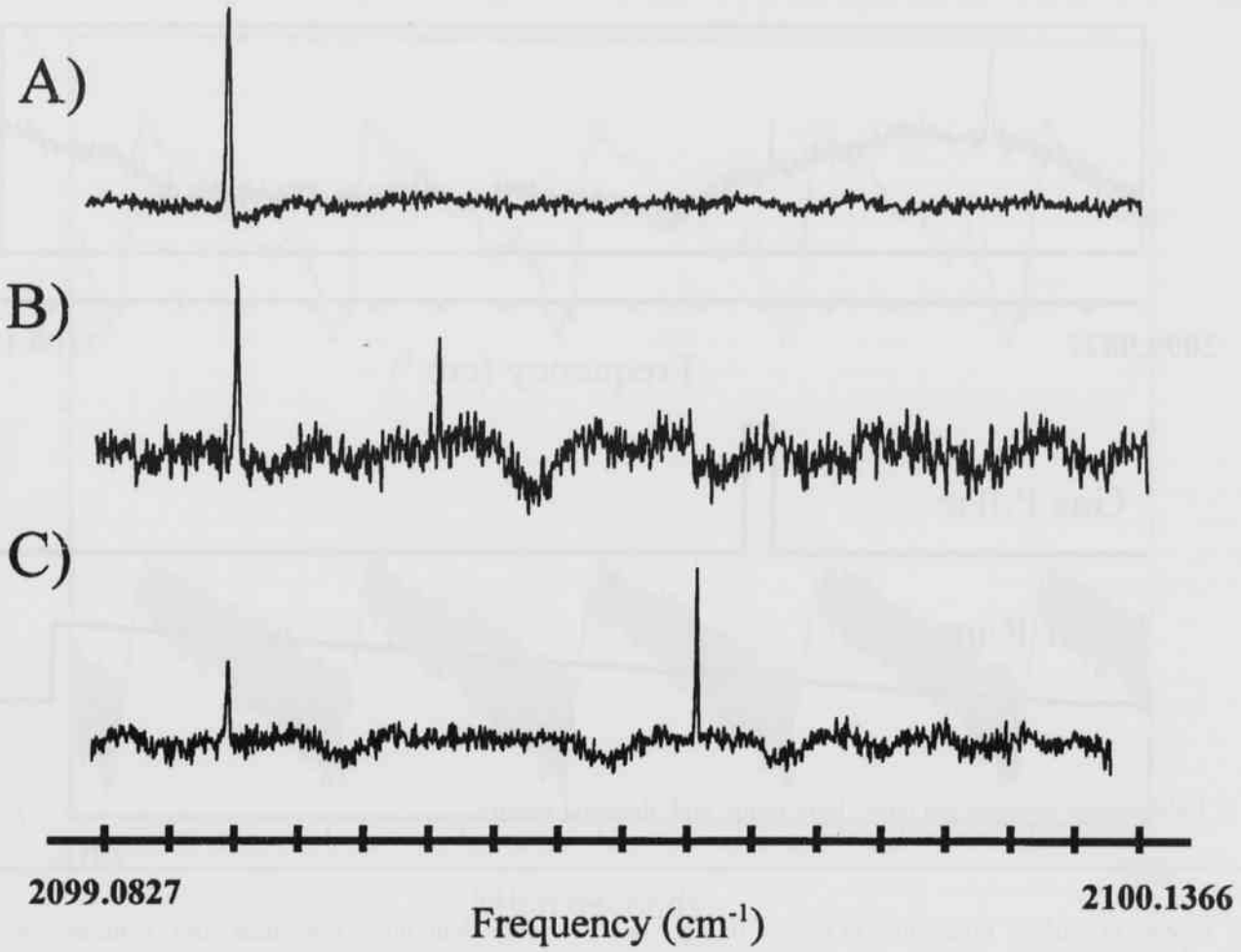

Fig. 4. Rovibrational spectra for the carbon monoxide molecule collected at different gas pulse positions along the voltage ramp.

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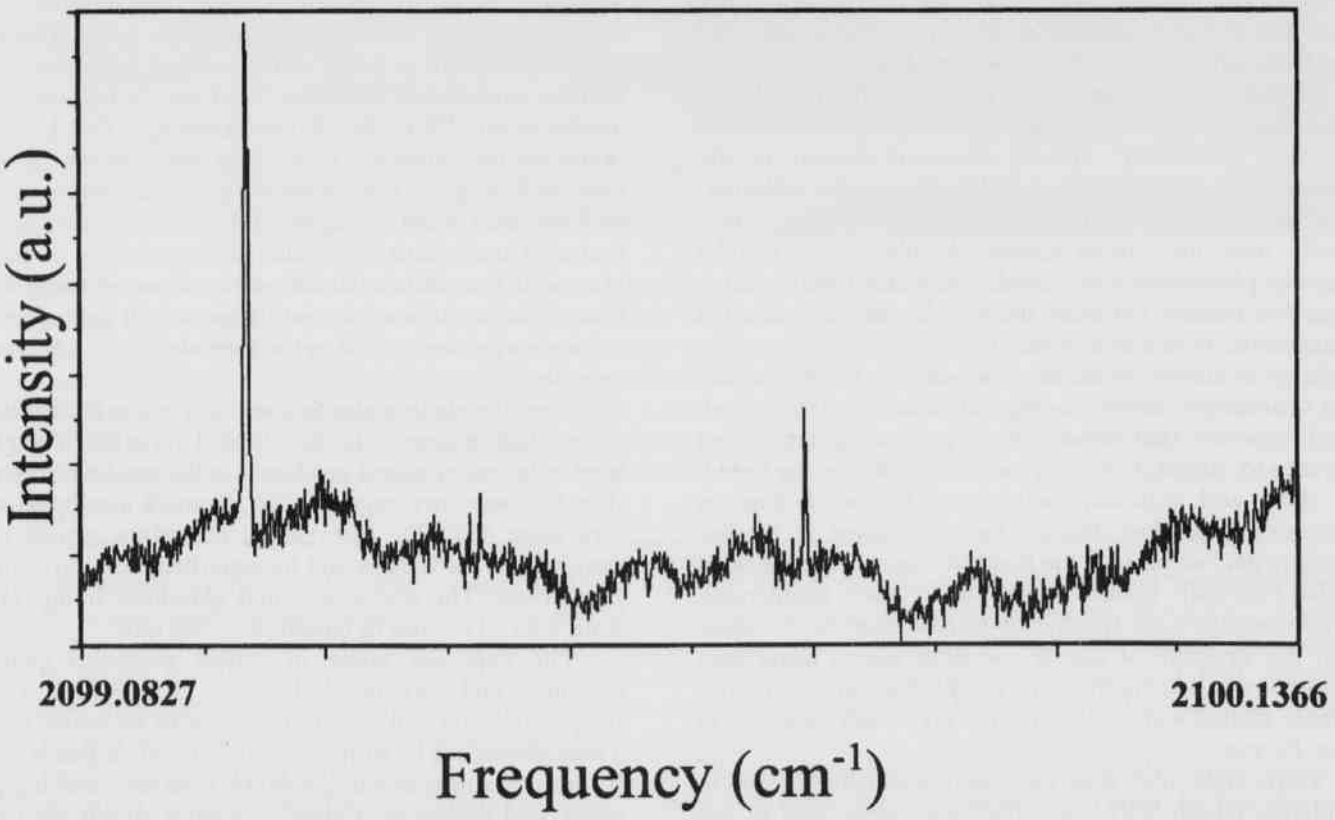

Fig. 5. Spectrum obtained by summing together the files shown in Fig. 4.

GENERAL NOTES

Caudal Courtship Glands in the Cave Salamander, *Eurycea lucifuga* (Caudata: Plethodontidae)

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Noble (1929) first reported courtship glands in the tail base of a plethodontid salamander, *Eurycea bislineata.* To date, these sexually dimorphic caudal glands have been demonstrated histologically only for *Desmognathus* (Noble, 1931), Eurycea (Noble, 1929; Sever, 1989; Trauth et al., 1993), and *Plethodon cinereus* (see Houck and Sever, 1994). The term "hedonic gland" was used in previous research (Gadow, 1887; Noble, 1927, 1929, 1931; Rogoff, 1927) to describe a cluster of glands that produced courtship pheromones. Because there was no evidence that the hedonic glands were indeed pleasure giving as the term implied, Arnold (1977) suggested the use of the term "courtship gland." Houck and Sever (1994) adopted the term courtship gland, and we follow their usage when referring to male sexually dimorphic glands within the skin of the tail base.

Caudal courtship glands are located on the dorsal base of the male's tail and hypertrophy during the breeding season; they presumably deliver secretions directly to the female during courtship (Sever, 1989). During the "tail straddling" walk females place their snouts on the male's rump directly over the caudal glands (Arnold, 1977). Caudal courtship pheromones presumably increase female receptivity, thus making her more likely to become inseminated by that male (Houck and Sever, 1994).

Little is known about the reproductive biology of the cave salamander (*Eurycea lucifuga*) in Arkansas. Trauth et al. (1990) reported that females undergo vitellogenesis from February to August; however, no investigation on the breeding cycle and courtship activity of *Eurycea lucifuga* in Arkansas animals has, thus far, been published. In the following paper, we provide the first histological description of caudal courtship glands of the male cave salamander, *Eurycea lucifuga.* Our specific objectives were to: 1) document the structure of caudal courtship glands using light microscopy and 2) compare the morphology and secretions of these glands with similar glands previously reported in other *Eurycea.*

Thirty-eight adult male cave salamanders (45-61 mm in snout-vent length [SVL], $\bar{x} = 55.9$ mm) were used in this study. The animals were taken from the Arkansas State University Museum of Zoology (ASUMZ) and from the personal collection of S. E. Trauth (SET). Specimens were collected from caves in the following counties of Arkansas: Fulton, Independence, Izard, and Stone. Collection dates were from December 1977 to July 1997. The visible glandular hump on the mid-dorsal region of the tail was measured and removed; in addition, an equivalent region of skin was excised from animals that did not possess these protuberances. The tissue samples were prepared for light microscopy using histological techniques outlined by Humason (1979); briefly, these steps were as follows: 1) dehydration in a graded series of ethanol, 2) clearing in xylene, and 3) embedding in paraffin. The tissue samples were oriented in the paraffin so that transverse or frontal sections could be obtained in a complete series. The tissue samples were cut at 8 µm using a rotary microtome. Four staining procedures were used and are as follows: hematoxylin-eosin (H&E) for general cytology, Pollak (Pollak) trichrome for connective tissues and mucosubstances, alcian blue 8GX at pH 2.8 for sulfated glycosaminoglycans, and periodic acid-Schiff's reagent (PAS) for general carbohydrates. These stains were alternately used on sequential groups of four slides. Glands were measured using a calibrated ocular micrometer and reported in µm; glandular volumes were derived using the formula for the volume of a cylinder.

Caudal courtship glands found in *Eurycea lucifuga* do not show a high degree of morphological variation. The glands tend to be either round or oblong in the pre-secretory stage (Fig. 1A), secretory stage (Fig. 2A, B, and C), and post-secretory stage (Fig 2D). The caudal courtships glands reside deep within the dermis and lie superficial to a layer of adipose tissue. The entire, elevated glandular hump ranged from 5.02 –11.9 mm in length ($\bar{x} = 7.69$ mm).

The epithelial lining of caudal courtship glands is columnar and variable in thickness ($\bar{x} = 60.2 \pm 5.2$ µm, range, 29.2 - 99.3, n = 30) in relation to secretory activity. These glands can be distinguished from other glands (namely, mucous and granular glands) by their size, staining properties, and secretions. Caudal courtship glands are usually greater in width ($\bar{x} = 168.2$ µm; range, 46.2 - 365.7, n = 130) and height ($\bar{x} = 190.1$ µm; range, 42.0 - 439.0; n = 130) than

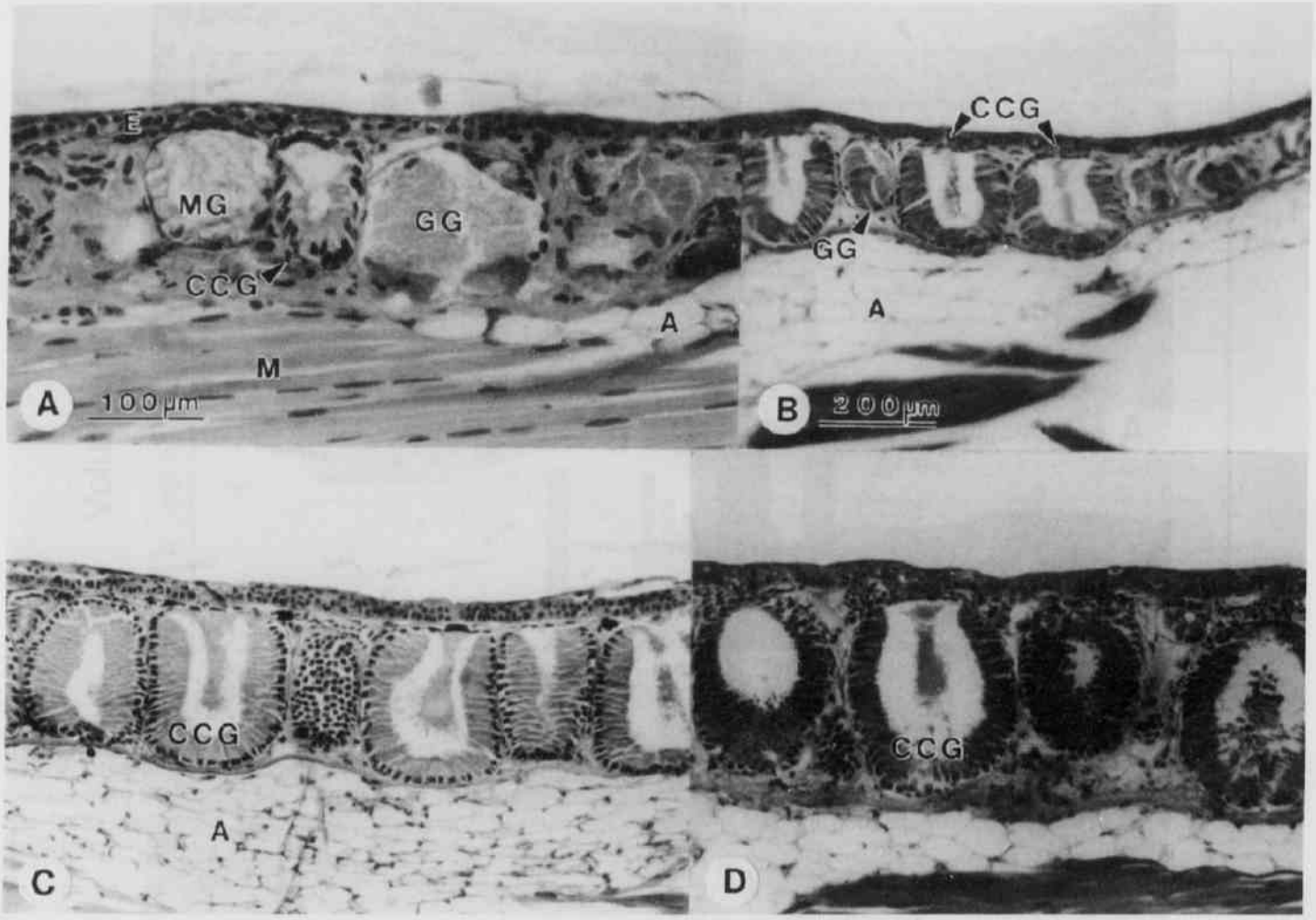

Fig. 1. Photomicrographs of sagittal sections through the mid-dorsal region of the tail directly above and posterior to the vent in *Eurycea lucifuga* illustrating the caudal courtship glands and their relationship to other epidermal glanda. A. Section of male skin (ASUMZ 20882) stained with H&E showing adipose tissue (A), mucous glands (MG), granular glands (GG), caudal courtship glands (CCG), a thin epidermis (E), and the dorsal musculature (M). Notice the relationship in size of the caudal courtship glands to the mucous and granular glands (specimen collected in February) before onset of the breeding season. B-D. Skin (ASUMZ 8147, 13966, SET 3841, respectively) stained with Pollak stain illustrating the relative increase in volume of the caudal courtship glands compared to other glands through the breeding season. Abbreviations the same as in A. Line in B the same for C and D.

either granular glands (width: $\bar{x}$ = 132.4 µm; range, 96.8 - 161.5; n = 19; height: $\bar{x}$ = 98.3 µm; range, 76.9 - 126.9, n = 19) or mucous glands (width: $\bar{x}$ = 64.3, µm; range, 38.5 - 107.7; n = 17; height: $\bar{x}$ = 48.2 µm; range, 19.2 - 103.8; n = 17). In addition, granular and mucous glands are mostly circular (Fig. 1A and B), whereas the caudal courtship glands are always barrel-like in shape (Fig. 1B and C).

Seasonal variation was observed in the secretory activity of caudal courtship glands of *Eurycea lucifuga* in Arkansas (Fig. 3). In specimens collected from October to early March caudal courtship glands were in a regressed state with most having little or no secretions. In contrast, caudal courtship glands examined from May-August possessed large amounts of secretory material and had greatly increased in size; the largest glandular volumes were observed in July.

The staining properties of the glandular secretions are similar to those that were reported in other *Eurycea* (Sever, 1989; Trauth et al., 1993). Glandular gland secretions are eosinophilic using H&E and Pollak, but they show no reac-

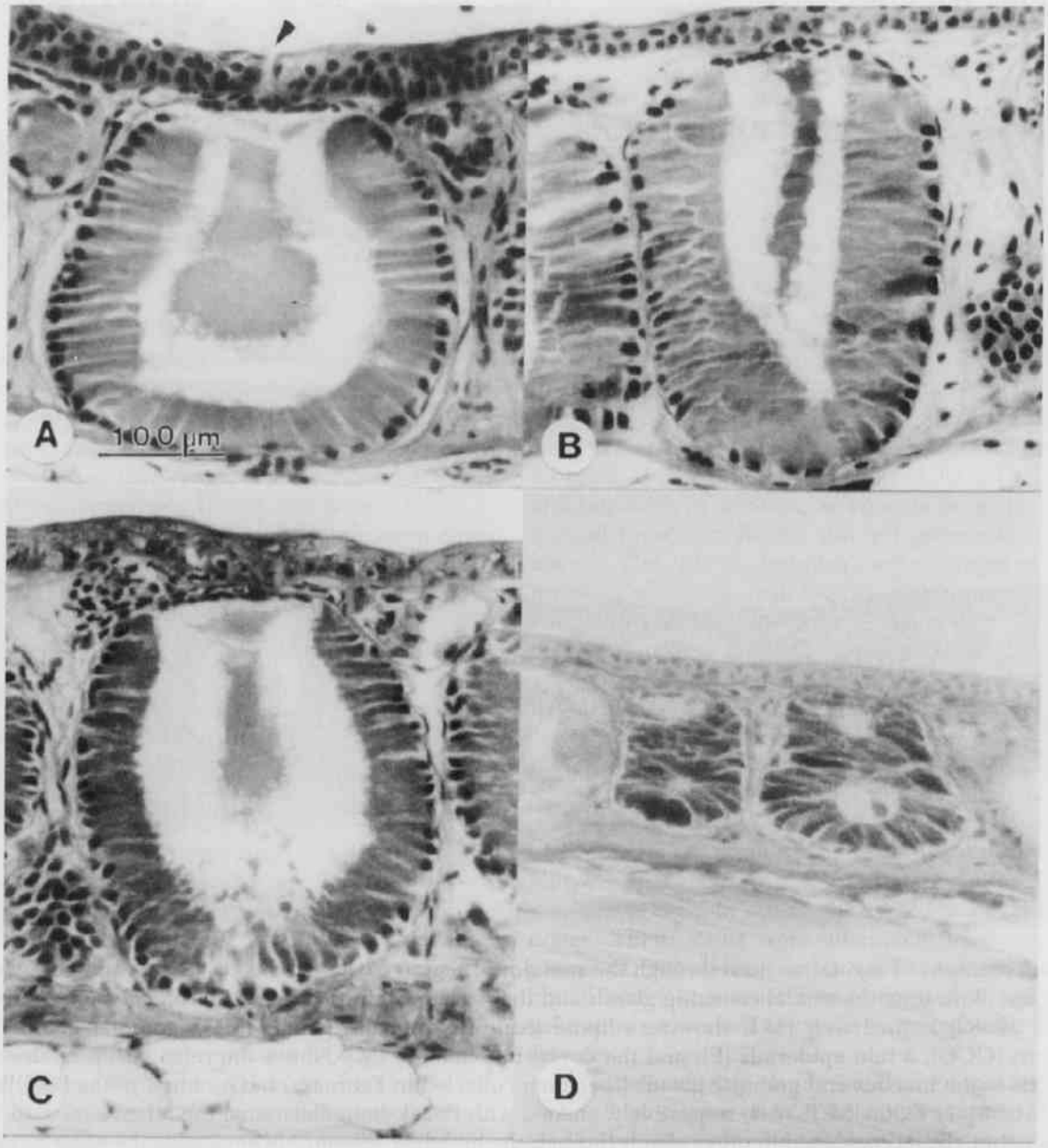

Fig. 2. A. Skin of male *Eurycea lucifuga* (ASUMZ 13966) stained with H&E illustrating the presence of a mucoprotein (eosinophilic) and columnar cells with basal nuclei; arrow indicates the duct opening. B-C. Skin (ASUMZ 13964; SET 3841, respectively) stained with Pollak stain illustrating the presence of mucosubstances. The epithelial lining of the caudal courtship gland appears light purple; the secretory column is a dark purple, except for portions that stain a dark brown to red. D. Skin of male (ASUMZ 14434) stained with PAS illustrating the regressed condition of the CCG following the breeding season (epithelial lining magenta in coloration). Line in A is the same for B-D.

tion with alcian blue, whereas the mucous glands contain a fibrous secretion that stains positive with alcian blue and basiophilic in H&E and Pollak. The staining characteristics of the caudal courtship glands indicate that a mucoprotein is involved as the secretory product (Sever, 1989; Trauth et al., 1993). In *E. lucifuga*, the secretion of the caudal courtship glands is PAS positive, alcian blue negative, and is eosinophilic using H&E. Staining with Pollak produced some mixed results. In many cases the secretion stained a light to dark blue, but in others the secretion was a dark

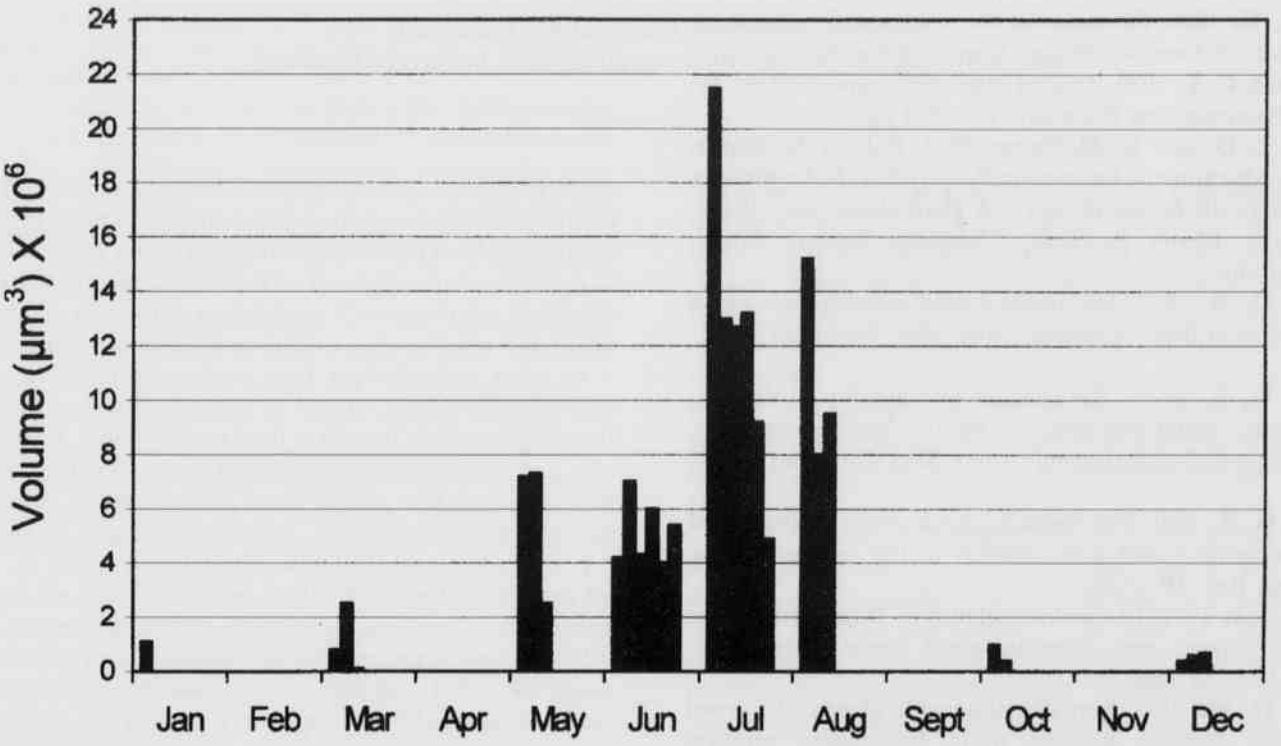

Fig. 3. Seasonal variation in average glandular volume of caudal courtship glands from 28 *Eurycea lucifuga*. Volumes represent values from five of the largest glands per specimen; the SVL's of specimens were as follows (linear order viewed in histogram): Jan - 58; Mar - 55, 57, 51; May - 58, 56, 55; Jun - 54, 58, 54, 58, 58, 54; Jul - 60, 54, 60, 58, 57, 61; Aug - 59, 55, 56; Oct - 61, 48; Dec - 53, 50, and 52.

brown or a shade of red.

The caudal courtship glands of *E. lucifuga* are similar in several respects to those of other species of *Eurycea* (*E. bislineata*; *E. cirrigera*; *E. junaluska*; *E. nana*; *E. wilderae*) as reported by Sever (1985, 1989) and in *E. multiplicata* (Noble, 1931). For instance, the round to barrel-like structure of these glands in the hypertrophied stage and the staining properties were consistent. The size of the caudal courtship glands in *E. lucifuga* is larger than those found in the other species of *Eurycea*, except for *E. longicauda melanopleura* (Trauth et al., 1993). *E. lucifuga* in the present study averaged around 8.2 mm greater in SVL compared to the *E. l. melanopleura* examined by Trauth et al. (1993).

In summary, cave salamanders (*Eurycea lucifuga*) were investigated for the presence of sexually dimorphic glands in the tail base. These multicellular, acinar, exocrine glands (caudal courtship glands) lie deep within the dermis in male *Eurycea* and produce a hypertrophied mid-dorsal area posterior to the vent. Caudal courtship glands can be distinguished from other glands (namely, mucous and granular) by morphology as well as the staining properties of the secretions. We found seasonal variation in the development of these glands; the glands exhibited their greatest volume in July at a time coinciding with ovarian enlargement in females and were least in volume during the winter months.

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Nutritional Condition and Reproduction of Deer at Fort Chaffee, Arkansas

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The health of any wildlife population is a function of the quality of habitat, and the primary resource affecting habitat quality is often food. The balance between food availability and requirements is reflected in the nutritional condition of individuals within the population. Consequently, biologists routinely monitor condition indices such as body weight, fat reserves, blood chemistry, and reproductive rates as a means of assessing changes in habitat quality (Harder and Kirkpatrick, 1993). When food is limited, body weights and fat reserves decline, and reproductive performance, e.g. age of puberty, ovulation rate, birth weight, and recruitment of offspring, is negatively affected. To improve the nutritional status of game populations, wildlife managers can (1) increase the amount of food available to each individual by using harvests to reduce population size and intra-specific competition, or (2) increase the food resource through habitat manipulation (Caughley and Sinclair, 1994). Of these two options, the former is often preferred because it is easier and less costly.

This paper reports the results of a study conducted from 1991 to 1995 to assess the nutritional condition of white-tailed deer (*Odocoileus virginianus*) on Ft. Chaffee military base in western Arkansas. A baseline survey was conducted in 1991 because hunters and wildlife managers expressed concerns that resident deer were poorly nourished, as indicated by low body weights and poor antler development. We continued to monitor the nutritional condition of this population over the next 4 years to investigate whether nutritional indices improved after managers reduced the density of the population by increasing harvests and increased the quantity and quality of the food by improving habitat. The specific objectives were to (1) evaluate the age-structure of deer harvested between 1991 and 1995, (2) quantify the nutritional condition of the population before and during this deer management program, (3) survey the prevalence of common diseases in the population, and (4) estimate reproductive rates and the timing of reproduction.

Study Area.--This study was conducted on Ft. Chaffee, a 29,000 ha army base in western Arkansas. Prior to 1990, the Arkansas Game and Fish Commission (AGFC) had primary responsibility for wildlife management on the base. That responsibility shifted to the Department of Army (DoA) in 1990.

The topography of the area is diverse, ranging from low floodplains to gently sloping terraces, to hills with peaks near 300 m elevation. The climate is one of mild winters and warm summers. Mean rainfall is 107 cm with much of the precipitation falling in the spring. Winter is the driest month, but significant droughts often occur in July and August. Evaporation rates during these months can be as high as 1 cm per day (Cox et al., 1975). Soils in the valleys and low terraces are poorly drained, acidic, and low in natural fertility with a shallow fragipan that restricts the penetration of roots and slows the percolation of water. Hilltops and slopes contain soils which are well-drained, but shallow, droughty, and stony with low to moderate fertility (Cox et al., 1975).

Much of the land comprising Ft. Chaffee was cleared and used for pasture and hay crops during the first 4 decades of this century. Intensive farming and overgrazing severely depleted soil fertility by the time Ft. Chatfee was established in 1940. Much of this land has reverted to trees, particularly drought-tolerant oaks (*Quercus* spp.), hickories (*Carya* spp.), and pines (*Pinus* spp.) on the hills and ridges. Ash (*Fraxinus* spp.), maple (*Acer* spp.), and cottonwood (*Populus deltoides*) dominate bottomland forests. Forage and browse species are abundant, but are likely of poor quality. Summer droughts and a year-round schedule of military activities lead to frequent fires, creating a mosaic of open, early-successional fields interspersed with the forests (Sturdy et al., 1991).

Beginning in 1990, the DoA initiated an active program of habitat improvement for deer. Approximately 11,000 ha were scheduled for prescribed burning on a 3-year rotation (3,600 ha/yr) to improve soil fertility and maintain early-successional communities. Habitat was further improved by planting 80 ha of supplemental food plots each year in 0.25-0.5 ha plots. These contained mixes of clover, wheat, millet, milo, and lespedeza. In addition, all areas of pronounced soil disturbance due to military activities were re-seeded to legumes and grasses as conditions permitted (Sturdy et al. 1991).

The first managed deer hunt on Ft. Chaffee occurred in 1961 when the AGFC acquired a license to manage the wildlife resources. Initially, deer seasons on the base coincided with statewide seasons and were "antlered bucks only" hunts. These hunts are believed to have contributed to a sex ratio skewed heavily towards females by the late 1980's. The primary evidence for this is that adult females outnumbered adult males in annual spotlight counts by approximately 7 to 1 in 1990 and 1991 (unpubl. data, Environmental Branch, Ft. Chaffee). The perceived need to

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balance sex ratios in the herd led to limited "either-sex" hunts during 1988-1990, during which hunters using muzzleloaders were allowed to harvest females as well as males. Either-sex hunts were expanded to include all hunters using rifles or muzzleloaders in 1991.

Harvesting Deer and Condition Assessment.--Ft. Chaffee was divided into 12 compartments, and hunters were assigned to these compartments to distribute hunting pressure evenly across the area. All hunters were required to check harvested deer at a check station throughout the 5-year study. Deer were sexed, aged by tooth wear and replacement (Severinghaus, 1949), and weighed on a platform scale to determine body weight. Antler dimensions were measured on all antlered males, including number of tines greater than 2.5 cm in length, circumference of the main beam 2.5 cm above its base, and antler spread measured at the widest point of the rack.

During the 1991 and 1995 deer seasons, hunters were asked to bring antlerless deer in whole. These deer were weighed (whole carcass weight), eviscerated, and reweighed (dressed weight). Fresh blood (40 ml) was collected from randomly-selected deer by severing the aorta, drained into clean vials, and centrifuged at 2,000 RPMs for 10 minutes. Serum was decanted into vials, frozen, and transported to a diagnostic laboratory for serum chemistry analyses, including blood urea nitrogen (BUN), glucose, total protein, albumin, albumin/ globulin ratio, calcium, phosphorus, cholesterol, and triglycerides. In addition, a 5-10 ml serum sample from each deer was sent frozen to the Southeastern Cooperative Wildlife Disease Study Laboratory (SCWDS) at the University of Georgia for antibody screening. These samples were tested for 7 common diseases of deer including brucellosis, bovine viral diarrhea (BVD) virus, infectious bovine rhinotracheitus virus, parainfluenza 3 virus, epizootic hemorrhagic disease (EHD) virus serotypes I and II and leptospirosis.

Both kidneys and adhering kidney fit were removed and weighed for determination of the kidney fat index (KFI). KFI is the ratio of the weight of trimmed kidney fat divided by the weight of the kidneys multiplied by 100 (Riney, 1955; Warren and Kirkpatrick, 1982).

Female reproductive tracts (ovaries, oviducts, uterus and cervix) were removed from female carcasses and fixed in 10% formalin (Golley, 1957). In the laboratory, ovaries were thinly sliced using a scalpel. All corpora albicantia (CA) and corpora lutea (CL) were counted in both ovaries (Teer et al., 1965). CL larger than 3 mm in diameter were recorded as CL of pregnancy (CLP), whereas CL smaller than 3 mm were considered accessory CL (Mansell, 1971). The presence of one or more CLP was evidence of current pregnancy, whereas CA's were evidence of pregnancy and ovulation rates in the previous year (Woolf and Harder, 1979). Each uterus was opened and drained into a dissecting tray for examination. Macroscopic embryos were counted, measured and sexed (if sufficiently developed). The age of each embryo was estimated using crown-rump length (Harnilton et al., 1985). These ages could be used to back date embryos to the conception date.

All data were analyzed using the SAS statistical package (SAS Institute 1987). Differences in body weights for each sex-age class and differences in antler measurements among years were tested using ANOVA with Tukey's mean comparison test to find differences of means. Differences in mean serum values, ovulation rates, and KFI's between the 1991 and 1995 samples were tested using two-sample t-tests. The x^2 contingency test was used to test for differences in the frequency of yearling males with branched versus unbranched antlers. All tests were conducted at $\alpha = 0.05$.

Age-structure of Harvested Deer.--Hunters harvested 2,627 deer during the 5-year study (Table 1). The largest harvest was in 1991 when 736 deer were taken. The total number of hunters participating ranged from 3,136 to 3,617 during the first 4 years. Hunter success during this period varied from 20.3% to 13.5%. In 1995 the number of permits was reduced to 2,370; only 265 deer were harvested, and hunter success fell to 11.2%.

Adult females comprised the largest percent of the harvest throughout the study, and the percent of total harvest that was adult female varied little (35-39%) each year (Table 1). The large harvest of this class was consistent with the management goal of reducing the proportion of adult females in the population and balancing the sex ratio. Concurrently, the proportion of adult males in the harvest rose steadily from 13% in 1991 to 19% in 1995. The ratio of adult females to adult males in the harvest during this period dropped from 2.9:1 to 1.9: 1, suggesting that liberalizing the harvest of females was leading to a more balanced sex ratio. The proportion of fawns harvested remained quite constant (10-15% females; 11-14% males) across all years, suggesting that the increased harvest of females did not

Table 1. Number of deer in each sex-age class harvested during the firearm deer seasons on Fort Chaffee, AR, 1991-95.

Class	1991	1992	1993	1994	1995	Total
Female fawn	77 (11%)	74 (12%)	65 (15%)	57 (10%)	29 (11%)	302 (12%)
Female yearling	74 (10%)	49 (8%)	26 (6%)	47 (8%)	24 (9%)	220 (8%)
Female adult	265 (36%)	241 (37%)	158 (37%)	215 (39%)	92 (35%)	971 (37%)
Male fawn	105 (14%)	81 (13%)	61 (14%)	72 (13%)	30 (11%)	349 (13%)
Male yearling	122 (17%)	101 (16%)	47 (11%)	80 (14%)	41 (16%)	39 (15%)
Male adult	93 (13%)	100 (16%)	66 (16%)	86 (15%)	49 (19%)	394 (13%)
Total Harvest	736	646	423	557	265	2,627

affect the proportion of fawns in the population.

Although hunters periodically expressed the opinion that the harvest of females was too heavy, this view is not supported by the high, consistent proportion of adult females in the harvest over this 5-year period. We speculate that the fewer number of deer harvested and lower hunter success in 1995 were due to the low number of permits issued, not overharvest. This is supported by the high positive correlation ($r = 0.925$; $P<0.05$) between the number of permits issued and hunter success rates.

Nutritional Condition of Deer.--Body weight is one of the oldest methods of directly assessing the nutritional status of deer and indirectly assessing habitat quality (Park and Day, 1942; Severinhaus, 1955). Weight is often the only index of condition available to wildlife managers and can be a good indicator of temporal changes in habitat quality if weights are collected in the same season and corrected for age and sex (Brown, 1984; Dinkines et al., 1991).

Deer harvested on Ft. Chaffee in 1991 were lighter than their counterparts in the Arkansas Ozark Mountains and on Holla Bend National Wildlife Refuge, located about 100 km east of Ft. Chaffee (Table 2; Torgerson and Porath, 1984; Nelson, 1991). Deer on Holla Bend were generally 2-25% heavier than those on Ft. Chaffee. However, Holla Bend provides a favorable nutritional environment with cropfields covering about 50% of the area. Consequently, these deer were expected to be heavier. In contrast, deer in the Ozarks occupy ranges with infertile soils and less agriculture, and these deer are among the lightest in the Midwest oak-hickory forest region (Torgerson and Porath, 1984).

The low body weights among Ft. Chaffee deer were reason for concern. Eve (1981) citing data from Oklahoma, Texas, and Kentucky suggested that chronically overpopulated deer herds "approach a minimal survival weight, and this weight is often in the vicinity of 65-75 pounds for field dressed yearling or older bucks." Yearling males on Ft. Chaffee averaged 76.5 lbs. in 1991 and had averaged 71.6 lbs. in 1989 (unpubl. data, Environmental Branch, Ft. Chalfee). The low body weights recorded in 1991 were particularly worrisome because that year had been mild with ample precipitation and above average acorn production (J. Sturdy, DoA. Ft. Chaffee, pers. comm.). The chronic low body weights among resident deer were thought to result from (1) high deer densities, (2) soils and forage that are low in nutrients, and (3) the relative scarcity of crops, which provide high quality, supplemental foods throughout most of the region.

Body weights of yearling and adult males increased from 1991 to 1995 after intensive harvesting and habitat management began (Table 3). Fawns also tended to be heavier, except in 1994, a drought year when the weights for fawns and all females were low. The weights of juvenile and adult females did not change during the 5-year period. The energy demands of gestation and lactation through spring and summer may limit growth and fattening in mature females. Further, mature females had been more comparable in weight to other deer in the region before intensive management began.

Antler Dimensions.--Antler growth in males is affected by age, nutrition, and genetics (Smith et al., 1983; Ullrey, 1983). Antler dimensions can be useful indicators of habitat quality. Males inhabiting good habitat with good quality food produce more tines and larger main beams (French et al., 1956; Cowan and Long, 1962). Gore (1984) and Scribner

Table 2. Comparison of eviscerated body weights of deer harvested on Fort Chaffee in 1991 with the weights of deer in other regional populations.

	Fort Chaffee			Arkansas Ozarks[1]			Holla Bend NWR[2]		
Age-class	N	Mean	SE	N	Mean	SE	N	Mean	SE
Female fawn	77	43	0.7	35	43	--	69	44	0.6
Female yearling	74	69	0.7	26	77	--	48	76	0.8
Female adult	264	79	0.4	47	80	--	101	87	0.9
Male fawn	103	47	0.6	35	50	--	74	50	0.7
Male yearling	121	77	0.7	202	87	--	52	98	1.1
Male adult	93	98	1.3	32	104	--	58	123	2.2

[1]Adapted from Torgerson and Porath, 1984.

[2]Data reported in Nelson, 1991

Table 3. Mean dressed weight of deer in each age-class on Fort Chaffee, 1991-95. Standard errors are shown in parentheses.

	FEMALE			MALE		
Year	Fawn[A]	Yearling[B]	Adult[C]	Fawn[D]	Yearling[C]	Adult[E]
1991	43 (0.7)^{a,b}	69 (0.7)^{a}	79 (0.4)^{a}	47 (0.6)^{b}	77 (0.7)^{b}	98 (1.3)^{b}
1992	45 (0.9)^{a}	70 (0.6)^{a}	79 (0.6)^{a}	52 (0.9)^{a}	79 (1.0)^{a,b}	98 (1.4)^{a,b}
1993	45 (1.0)^{a}	70 (1.6)^{a}	79 (0.6)^{a}	49 (1.2)^{a,b}	81 (1.3)^{a,b}	104 (1.8)^{a}
1994	41 (0.8)^{b}	68 (1.1)^{a}	78 (0.5)^{a}	47 (1.1)^{b}	79 (0.9)^{a,b}	103 (1.2)^{a,b}
1995	45 (0.9)^{a}	69 (0.9)^{a}	80 (0.9)^{a}	50 (1.1)^{a}	81 (1.2)^{a}	104 (2.1)^{a,b}

Mean weights for classes followed by different capital letters at $\alpha=0.05$ across all years.
Within columns, means followed by different trivial lettes at $\alpha=0.05$.
No interactions between age-class and year were found.

et al. (1984) reported that white-tailed deer, especially yearlings, have a much greater tendency to produce small "spike" antlers (no tines) in poor quality habitats.

In 1991, 69% of the yearling males harvested on Ft. Chaffee had spike antlers. Torgerson and Porath (1984) listed the typical percentage of spikes among yearlings in Arkansas and surrounding states as 17-33%. Eve (1981) reported that "studies of Oklahoma deer showed that 70 to 100% of yearlings on chronically overpopulated ranges had spike antlers, while at lower densities on other areas spike bucks comprised only 0 to 18% of the yearling buck class." Beam diameters among Ft. Chaffee yearlings harvested in 1991 averaged 15.4 mm, significantly smaller than average diameter of 19-20 mm for most deer in Arkansas, Missouri, and Oklahoma (Torgerson and Porath, 1984).

The proportion of yearling males with spike antlers decreased from 69% in 1991 to 63% in 1992 to 53% over the last 3 years of the study. We believe that this trend toward fewer spike bucks is an indication of healthier deer. Among adult males, the mean number of tines (7) did not differ significantly among years. However, the mean beam diameter did increase significantly from 19 mm in 1991 to 31 mm in 1995 ($t = 5.1$; $P < 0.05$).

Stored Fat and Blood Chemistry.--Fat reserves and blood parameters have been found to be useful indicators of nutritional status in deer. Blood chemistry often reflects the individual's short-term nutritional balance (days, weeks), whereas fat deposits indicate energy balance over longer periods (months) (Brown, 1984). Mech and Delgiudice (1985) reported that when white-tailed deer fatten, they first deposit fat in the bone marrow, then around the kidneys, then throughout the abdominal region, and finally on the back and rump. Stored fat is generally utilized in reverse order. Consequently, kidney fat (usually expressed as KFI) has been shown to be a useful indicator of energy balance over the middle ranges of nutritional condition (Ransom, 1965; Stockle et al., 1978).

We measured KFI's only in the adult and yearling female classes to assess changes in body fat. These classes were selected because they are the classes least affected by the timing of the hunting season. Fawns tend to put most energy into growth, and generally have low KFI's even on high planes of nutrition. During the fall mating season, the energy reserves of mature males are rapidly depleted as the season progresses. Consequently, adult and yearling females appear to be the best indicators of annual changes in fat reserves. The mean KFI of females harvested on Ft. Chaffee was relatively high (120) in 1991 and increased significantly to 290 in 1995 ($t = 6.05$; $P < 0.01$), suggesting higher levels of body fat and net energy in 1995.

Biologists began using blood serum chemistry to predict dietary protein and energy in deer during the 1970's (Brown, 1984). Serum composition reflects relatively short-term (hours to weeks) dietary intake. BUN (blood urea nitrogen) is positively correlated with dietary protein and is a good indicator of protein intake (Seal et al., 1972; Seal et al., 1978; Warren et al., 1982). Dietary energy is best measured by NEFA (nonesterified fatty acids), triglycerides, calcium, phosphorus, and cholesterol (DeCalestra et al., 1975; Seal et al., 1978; Warren et al., 1982). NEFA is usually considered to be the preferred indicator of dietary energy when collected from live deer, but triglyceride concentration is indicative of dietary energy and remains unchanged for several hours after death (Dinkines et al., 1991). We did not measure NEFA, but did evaluate triglycerides, calcium, phosphorus, and cholesterol levels in Ft. Chaffee deer.

Serum characteristics were analyzed in 36 adult female deer harvested in 1991 (Table 4). Mean BUN concentrations were low (13.4 mg/dl) and below values found in other regional populations. Dinkines et al. (1991) reported that deer occupying good habitat in Oklahoma had average BUN concentrations of 25 mg/dl, whereas those on poor range averaged 16.6 mg/dl. Low BUN levels suggests that dietary protein levels may be low for deer at Ft. Chaffee. In contrast, triglyceride, calcium, and phosphorus levels were high, indicating high dietary energy levels during the fall of 1991. Acorn production had been good in western Arkansas, and deer had fed heavily on them. We believe that the carbohydrates and fats supplied by these acorns contributed to a high energy plane and substantial fat reserves seen in these deer.

Serum levels were generally higher in 1995 after 4 years of herd reduction and habitat improvements (Table 4). Mean concentrations of BUN, total protein albumin, albumin:globulin ratio, phosphorus, and triglycerides were higher in 40 adult females harvested in 1995, although these differences were not significant ($P = 0.06$ - 0.52). Higher kidney fat levels, and higher concentrations of BUN, triglyc-

Table 4. Mean values for blood serum parameters measured in white-tailed deer harvested on Ft. Chaffee, AR in 1991 and 1995.

Blood Serum Parameter	1991	1995
Blood Urea Nitrogen (mg/dl)	14.1	14.5
Total Protein (g/dl)	6.9	7.5
Albumin (g/dl)	2.6	3.7
Albumin/globulin ratio	0.61	0.97
Phosphorus (mg/dl)	13.1	14.3
Triglycerides (mg/dl)	128	146
Calcium (mg/dl)	10.7	8.5
Cholesterol (mg/dl)	56	57

Table 5. Age-specific pregnancy and ovulation rates for female white-tailed deer on Fort Chaffee, AR in 1991 and 1995.

	1991			1995		
Class	N	% Breeding	$\bar{X}$ ova[1]	N	% Breeding	$\bar{X}$ ova[1]
Fawn	54	17	1.00	16	25	1.00
Yearling	33	98	1.26	16	100	1.50
Adult	138	99	1.87	93	100	2.22

[1] Mean number of ova/breeding female

Table 6. Percent prevalence of disease found in harvested deer on Fort Chaffee. Sample size was 40 deer in 1991 and 16 deer in 1995.

	Percent prevalence	
Disease	1991	1995
Bluetongue virus	0	0
Bovine viral diarrhea virus	0	0
Brucellosis	0	0
Epizootic hemorrhagic disease virus	10	18
Infectious bovine rhinotracheitis virus	0	0
Leptospira	8	6
Parainfluenza 3 virus	15	18

erides, and total protein in the blood serum of harvested females indicate that the nutritional plane of the Ft. Chaffee deer herd was higher in 1995 than in 1991.

Reproduction.--The beginning of the breeding season on Ft. Chaffee was estimated by back-aging fetuses to the dates of conception. Earliest conception occurred on October 7, but significant numbers of adult and yearling females did not breed until after October 29. The peak of breeding occurred between November 8-20. Fawns bred later than older deer; of 36 female fawns examined, only 2 (6%) had CLP before January. A previous study conducted on Holla Bend NWR showed that the peak of breeding occurred during mid- to late-November (Nelson, 1991), coinciding with the period when peak numbers of spermatozoa were found in the reproductive tracts of adult males (Nelson and Johnson 1990).

Over the past 30 years, substantial evidence has accumulated to indicate that nutrition is the primary determinant of reproductive performance in deer (Verme, 1969; Woolf and Harder, 1979). Dietary energy intake and not protein intake influences ovulation rates (Murphy and Coates, 1966). Studies have shown that does on higher nutritional planes 6 to 8 weeks before breeding produce significantly more offspring. Richter and Labisky (1985) found that a doe's productivity was linked to its nutritional plane but was also affected by deer density. Nutrition appears to have its greatest effect on the percentage of fawns breeding and the ovulation rates of adult does (Harder, 1980).

The percentage of female fawns breeding was low (17%) in 1991, but rose to 25% in 1995 (Table 5). Harder (1980) reported that approximately 48% of fawns bred in the Missouri Ozarks, and 56% bred in the agricultural region of that state. Only 24% of fawns bred statewide in Tennessee (Torgerson and Porath, 1984), and 27% bred on Holla Bend NWR in Arkansas (Nelson, 1991).

A high percentage of adult females breed in most deer populations, and the Ft. Chaffee population was no exception. Nearly all yearling and adult females had bred in 1991 and 1995 (Table 5). However, ovulation rates were higher in 1995 in yearlings ($t = 11.5$; $P < 0.05$) and adults ($t = 7.16$; $P < 0.05$) than in 1991. The higher reproductive rates found in 1995 appear to be further evidence that the deer population was in improved condition.

Prevalence of Disease.--Blood serum from 40 deer was screened for 7 common diseases of deer in 1991, and 16 deer were screened in 1995 (Table 6). The presence of antibodies to Parainfluenza 3 virus, EHD virus (serotype II), and Leptospira in individual deer indicated that these diseases were present in the population, but at relatively low prevalences. EHD is the most important endemic infectious disease afflicting deer in the U.S (Nettles and Stallknecht, 1992). Fischer et al. (1995) reported that more than 14,000 deer in a relatively small region of Missouri died due to hemorrhagic disease between August and October 1988. Population immunity to particular serotypes can vary greatly, and immunity to one serotype does not provide immunity for the others (Stallknecht et al., 1991). The prevalence of EHD in Ft. Chaftee deer was higher than in deer tested in the Arkansas Ozarks (0%), but lower than in deer tested in southeastern Arkansas (57%; D. Stallknecht, SCWDS, pers. comm.).

Nearly all of the indicators of herd health that were measured during this study suggested that the nutritional condition and reproductive rates of Ft. Chaffee deer improved from 1991 to 1995. Although body weights showed few significant trends, fat levels were higher, the percentage of spike bucks was lower, and blood parameters suggested that dietary energy and protein were higher in 1995. Finally, reproductive rates were higher in 1995 as indicated by more fawns breeding, and higher ovulation rates among yearlings and adults. While it is difficult to prove causality, it appears likely that the improved

condition of the herd was due largely to a management program that reduced deer density and improved habitat. Wildlife is a product of the land. The inherent limitations on habitat quality imposed by relatively infertile soils and periodic droughts mean that the Ft. Chaffee deer population may never reach a high nutritional plane relative to others in the region. However, a management program which maintains the population at or below current levels and leads to a balanced sex ratio should provide a healthy population and high reproductive rates.

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The Colonization of an Ozark Mountain City by the Asian Tiger Mosquito (*Aedes albopictus*)

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On 10 August 1993 three adult *Aedes albopictus* (Skuse) were collected within the city limits of Batesville, (Independence County) in northeastern Arkansas (Jamieson and Olson, 1995). This was the first known report of this species from the Ozark Mountains physiographic region of the state. At that time *A. albopictus*, commonly called the Asian tiger mosquito, had been reported from only three Arkansas counties: Grant County (Moore et al., 1988), Craighead County (Jamieson et al., 1994), and Jefferson County (Savage et al., 1994). However, based on information from neighboring states, it is likely that *A. albopictus* occurs statewide in Arkansas. This species has received considerable attention since its arrival in the United States due to its potential threat as a disease vector. Although not yet implicated in any disease epidemic in the U.S., its ability to become locally abundant and thereby restrict human outdoor activity greatly concerns mosquito control professionals.

After its discovery in Batesville in 1993, an investigation to locate production sites in the city ensued. Three major breeding sites were found, two of which were tire dealerships on the north and south margins of the city limits, while the third was a dump in the west-central part of town. *Aedes albopictus* is a container-inhabiting species that rarely oviposits outside of artificial containers, with automobile tires being the primary larval-production site. However, Jamieson and Olson (1995) reported collecting *A. albopictus* larvae from a variety of containers including flower pots, bird baths, barbecue grills, Christmas tree stands, and house gutters. In this study we follow up that work with a biting survey to determine how well distributed this species is in the city of Batesville and to provide data as to relative abundance. We are concerned about the impact this Asian immigrant will have on Arkansas cities that historically have not had mosquito problems.

Three study sites were established within the city limits of Batesville. Site #1 was in the west-central part of the city near the intersection of College and 8th Streets, approximately 1 km west of state highway 167. Site #2 was on the campus of Lyon College in the northeastern part of town, approximately 2 km east of highway 167. Site #3 was in Fitzhugh Park, located in the south-central region of the city at the intersection of Briar and 20th Streets. Each site was sampled twice monthly from April to October, the first sample was always taken during the first week of the month while the second sample was taken around the 15th. Each sample consisted of all adult female mosquitoes that could be captured during a 30 minute period with an aspirator or wide-mouthed vial as they attempted to take a blood meal from the sampler. The sampling always occurred within the 2 hour period before dusk with the intent of maximizing the chances of capturing diurnal, crepuscular, and nocturnal species. Adult female *A. albopictus* were distinguished from other native species using characters described by Darsie (1986). Once *A. albopictus* populations peaked at these three sites (July and August), samples were taken from 13 neighborhoods city-wide in order to determine how widely distributed the species has become in the city.

A total of four mosquito species was collected at site #1 during the study. *Aedes triseriatus* (Say) was the most abundant species in April with a total of 5 being collected. It was not encountered during the remainder of the study period. An individual *Culex salinarius* (Coq.) was collected in April and likewise was absent from all subsequent samples. Three *Aedes vexans* (Meigen) were collected at site #1, one in May and two in the early June sample. From the 15th of June to the end of the study period, *A. albopictus* was the only mosquito collected at site #1. Its population peaked in July when 33 individuals were collected (15 during the early collection, July 3rd and 18 during the middle of the month, July 15th) (Table 1).

Aedes albopictus was the only species collected at sites #2 and #3 during the study. Populations at these sites were substantially lower than at site #1. The explanation may be related to the number of oviposition sites available in these areas or their proximity to major production sites such as

Table 1. Biting collections of adult female *Aedes albopictus* (Skuse) at three sites in Batesville, Arkansas in 1997.

Site	April	May	June	July	Aug.	Sept.	Oct.
1	0	5	10	33	18	5	0
2	0	0	0	1	5	1	0
3	0	0	1	5	3	1	0

tire dealerships. It could also be related to the relative amount of vegetation at the site. According to Hawley (1988), *A. albopictus* is primarily a forest dwelling species that is rarely encountered in areas devoid of vegetation . Site # 1 is located in the residential area where Jamieson and Olson (1995) first collected the species in Batesville. There is an abundance of oviposition sites and cover, and it is < 1 km from the previously mentioned dump in the west-central part of town. Sites #2 and #3 are in public areas where one would expect to encounter fewer artificial containers for oviposition and the forest cover at these sites is less dense than at site #1. However, sites #2 and #3 are bordered on at least one side by a residential area.

When populations peaked in July and August, we expanded our collecting efforts in order to determine how well distributed the species is in the city. We collected biting adult female *A. albopictus* from 11 of the 13 neighborhoods sampled. The two that were negative were the most rural of the 13 sampled. This species has become widespread in the city of Batesville.

The main conclusion arrived at in this study is that *A. albopictus* can easily become locally abundant, and thus pestiforous, in communities in the Ozark Mountains physiographic region of Arkansas. Its true impact is more difficult to ascertain because of a lack of baseline data concerning mosquito abundance in areas of that region. While native mosquitoes such as *A. triseriatus* and *A. vexans* will readily take human blood, their current numbers appear too low to restrict any human outdoor activity. It is unclear what impact the arrival of *A. albopictus* has had on the distribution and abundance of native mosquito species, particularly those that are close ecological associates. *A. triseriatus*, commonly referred to as the treehole mosquito will readily utilize both treeholes and artificial containers as oviposition sites. However, because *A. albopictus* is a superior competitor in the artificial container habitat (Livdahl and Willey, 1991), *A. triseriatus* populations may have once been higher in the Ozarks prior to the *A. albopictus* invasion. Most lifelong residents of the region agree that historically the area has not had a significant problem with pestiforous mosquitoes prior to the arrival of this Asian immigrant.

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The Preparation of Methyl 5-Chloro-6-Fluoronicotinate by Fluoride-Chloride Exchange

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Several chloro and fluoronicotinic acids have been examined for hypolipidemic activity in dogs (Carlson et. al., 1972). It was demonstrated that 5-fluoronicotinic acid, 6-fluoronicotinic acid, and 5-chloronicotinic acid were effective for the supresssion of elevated free fatty acid levels, with the fluoroacids having longer duration. A few simple alkyl esters of these acids also showed some activity, presumably due to in vivo hydrolysis to the acids. While it would seem feasible to study possible hypolipidemic activities of nicotinic acids and esters with a dual combination of fluorine and chlorine on the pyridine ring, such studies have been limited by the relative nonavailability of these compounds.

In connection with our previous studies involving exchange of fluorine for chlorine in the pyridine 2- or 6-position by nucleophilic displacement (Setliff and DeFoggi, 1978), we saw the opportunity to prepare methyl 5-chloro-6-fluoronicotinate (a heretofore unknown compound) from methyl 5,6-dichloronicotinate, which is readily accessible. It has been known for decades that chlorine in the 2-or 6-position of pyridine is displaced easily by fluoride in boiling anhydrous dimethylformamide (DMF), provided a very strong electron withdrawing group (e.g. nitro or ammonium) is located at the *para* position (Finger and Starr, 1959). However, the more weakly electron withdrawing carbomethoxy group, although shown to be sufficiently activating to induce displacement of chloride by fluoride in the benzene system if a nitro group is also present (Finger and Cruse, 1956), had not been tested in a pyridine system. Thus, we attempted and were successful in the conversion of methyl 5,6-dichloronicotinate to methyl 5-chloro-6-fluoronicotinate as depicted in Fig. 1.

We previously attempted the fluoride exchange with various chloronicotinic acids, but the results were totally unrewarding. Only tars or intractable resins were obtained (Coop, 1996).

Melting points were determined on a Mel Temp II apparatus and are uncorrected. Elemental analysis was performed by Desert Analytics Organic Microanalysis, Tuscon, AZ. Proton NMR spectra were determined on a Bruker AC-F 200 MHz superconducting FT spectrometer with chloroform-d as solvent and tetramethylsilane as internal standard. Infrared spectra were obtained on a Nicolet 500 Magna FT-IR spectrophotometer, with samples deposited as films evaporated from chloroform onto a KBr plate. Methyl 5,6-dichloronicotinate was prepared as described previously (Setliff and Huie 1981). Potassium fluoride (fine powder) was purchased from Aldrich Chemical Company and was oven-dried at 110°C for several days prior to use. Dimethylformamide (Aldrich) was dried over neutral alumina for several days and distilled immediately before use (b.p. 158°C.)

The synthesis of methyl 5-chloro-6-fluoronicotinate was accomplished as follows. Methyl 5,6-dichloronicotinate 0.0049 mole) was placed in a 25 mL round-bottom flask and dissolved in DMF (2.5 mL). Dry potassium fluoride powder (0.6 g, 0.0098 mole) was quickly added, and a reflux condenser equipped with a calcium chloride drying tube was attached to the flask. The reaction mixture was stirred under gentle reflux for 1 hr with oil bath heating. The oil bath temperature was maintained at 155-158°C. The dark reaction mixture was cooled and transferred to a 250 mL 3-necked

Fig. 1. Nucleophilic displacement of chloride by fluoride at 158°C

flask, 10 mL of water was added, and the mixture was indirectly steam distilled. A white solid (0.30 g, m.p. 47-57°C) was filtered from the steam distillate. This material, shown by proton NMR to be a mixture of starting material and product, was returned to the reflux flask and once again heated with potassium fluoride (0.6 g) in DMF (2.5 mL) for an additional hour. Indirect steam distillation yielded the pure chlorofluoro ester as a fluffy white solid, 0.22 g , 24% yield, m.p. 66-68°C. IR: ν 1724 (C=O), 1068 (C-O) cm^{-1}.

^1H NMR: δ 8.75 (m), H_2 ; [8.45, 8.44 and 8.41,8.40] (d of d), H_4; 3.97 (s) CH_3. The pyridine ring proton signals of the starting dichloro ester [H_2 at 8.89 ppm (d) and H_4 at 8.36 ppm (d)] were not visible at high amplification, indicating reasonable purity. Anal. Calcd. for $C_7H_5NO_2FCl$: C, 44.35; H. 2.66; N, 7.39. Found: C, 44.13; H, 2.51; N. 7.41.

Although methyl 5-chloro-6-fluoronicotinate was sucessfully prepared and characterized, the low yield could not be improved upon due to a competitive reaction of the dichloroester with DMF. After the initial reflux of 1 hr and after the volatile solid was removed by steam distillation, cooling of the steam distillation pot afforded a nonvolatile organic material (0.20 g) of m.p. 147-150°C. Preliminary indications based on infrared and ^1H NMR data suggest a possible imminium salt structure (Fig. 2).

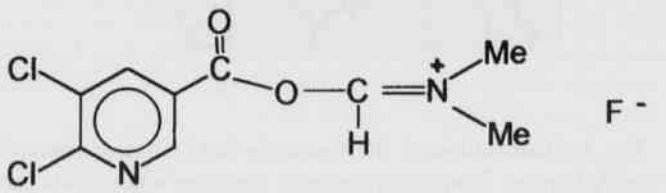

Fig. 2. Likely structure of the imminium salt formed competitively.

This material was not characterized further. Reaction times longer than 1 hr led to increased amounts of the presumed imminium salt and virtually no steam volatile ester; whereas shorter reaction times and lower reaction temperatures resulted in recovery of mostly unconverted starting material.

Although Finger (Finger et al., 1963) had demonstrated the superiority of dimethyl sulfone over DMF as a solvent in fluoride-chloride exchanges in pyridine systems, no examples of chloroester substrates were mentioned. With the hope that the use of dimethyl sulfone would eliminate our competitive reaction, we employed this solvent under a variety of conditions. However, no pure steam volatile products could be isolated.

In conclusion it appears that the ester group offers only very weak activation to chloride displacement in the absence of strongly electron withdrawing groups. Actually, the chlorine in the 5- position significantly aided activation since in a control experiment we observed that methyl 2-chloronicotinate gave only spectral traces of the fluoroester.

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Arkansas Range Extension of the Seminole Bat (*Lasiurus seminolus*)

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The Seminole bat, *Lasiurus seminolus* (Rhoads) is medium-sized and similar in general appearance to the red bat (*Lasiurus borealis*). Differences occur in coloration; the Seminole bat is a rich mahogany-brown color, lightly frosted with white above and paler below (Sealander and Heidt, 1990). Seminole bats are considered a treedwelling species occurring most often in the deep south. This bat's range has been strongly associated with that of Spanish moss (*Tillandsia usneodes*) in which it roosts. During summer months Seminole bats range from South Carolina to the gulf coast of Texas and Mexico. Individuals have been found as far north as Pennsylvania and New York (Barbor and Davis, 1969). Historically, this bat was generally considered to occur in the two tiers of counties that make up southern Arkansas (Sealander and Hoiberg, 1954; Baker and Ward, 1967; Sealander, 1979; Hall, 1981).

Heath et al. (1983) reported capturing an adult female Seminole bat at the entrance of an abandoned mine in Polk County. This specimen extended the range in Arkansas 57 km north of previously reported records.

Saugey et al. (1989) reported capturing Seminole bats in Garland, Logan, and Yell counties of Arkansas. This extended the range of the species 71 km north of the 1982 location in Polk County reported by Heath et al. (1983; 1986). This was a major range extension for this species, but it still remained south of the Arkansas River in Arkansas.

Kennedy et al. (1984) reported the Seminole bat from the Memphis, Tennessee area. This would be slightly more northerly than the most northern reports from Arkansas.

On 7 August 1997, an adult female Seminole bat was mist-netted over a pond in Baxter County in north central Arkansas (Fig. 1). The pond is located within the Sylamore Ranger District of the Ozark National Forest.

A female seminole bat was turned into the Arkansas Department of Health Rabies Lab. This bat was collected 20 September 1997, from Pine Bluff, Jefferson County and was positive for rabies (Fig. 1). This bat was within the range previously established by Saugey et al. (1989), but is a new county record for the species.

A female seminole bat was captured in Franklin County on 5 September 1998. This bat was captured over an upland pond in the Boston Mountain Ranger District of the Ozark National Forest (Fig. 1). The bat was measured, banded (#2133) and released.

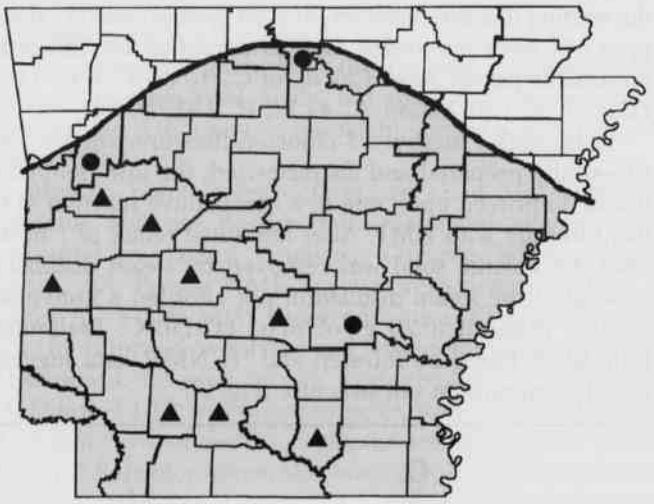

Fig. 1. Distribution of the seminole bat (*Lasiurus seminolus*) in Arkansas. Triangles represent counties where bats have been previously recorded; the circles represent the counties where this bat was captured in this study.

The Baxter and Franklin County captures extend the range of Seminole bats approximately 115 km north of previous published records in Arkansas. These specimens also extend the range approximately 73 km north of Seminole bats collected in Tennessee.

Voucher specimens have been placed in the Collection of Recent Mammals at Arkansas State University.

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Rediscovery of *Marsilea vestita* subsp. *vestita* in Pulaski County, Arkansas After 162 Years

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We report the first vouchered record of *Marsilea vestita* Hook. and Grev. subsp. *vestita* from Pulaski County Arkansas in 162 years. Two patches of the hairy water fern, *M. vestita* subsp. *vestita* were discovered by W. Shepherd on 20 September 1997 at the edge of a backwater pond along the Arkansas River at Murray Park in Little Rock. Prior to this record, the most recent collection of this species from Pulaski County was taken from "the margin of small swamps in the deep bottom woods on the Arkansas River, not far below Little Rock" in July of 1835 by the German botanist and physician George Engelmann. Witsell visited Shepherd's site to make collections on 24 September 1997 and again on 9 October 1997 with J.H. Peck to conduct a census and evaluate the status of the population. A total of 53 patches covering 124 m^2 was discovered along the shoreline of backwater ponds behind a series of five wingdam-dredge-spoil islands created by the Corps of Engineers' McClellan-Kerr Navigation Project. Voucher specimens are located in the LRU herbarium at the University of Arkansas at Little Rock [*Shepherd 452* (LRU), *Witsell 18* (LRU)].

Marsilea vestita subsp. *vestita* occurs over the western U.S., but is most abundant in the central Great Plains region (Johnson, Systematics of the new world species of *Marsilea* (Marsileaceae). Vol. 11. Systematic Botany Monographs. University of Michigan at Ann Arbor. 1986). Arkansas populations are at the eastern edge of the species's range and are rare enough for the species to be on the Arkansas Natural Heritage Commission's special plant list of rare and sensitive species. Other occurrences of *Marsilea vestita* subsp. *vestita* in Arkansas have been recorded in Arkansas, Ashley, Bradley, Chicot, Crawford, Desha, and Faulkner counties as *Marsilea mucronata* A. Braun, *M. uncinata* A. Braun and *M. vestita* var. *uncinata* (A. Braun) Baker (Peck, J. and C. Taylor. Checklist and distribution of Arkansas Pteridophytes. Proc. Arkansas Acad. Sci. 49:130-137, 1995).

There is great genetic and environmental variability in the genus *Marsilea* and taxa are often difficult to determine in the absence of the more taxonomically reliable sporocarps. However, the relative development of roots and lateral shoots, the degree of development of lateral shoots, and leaflet shapes are of some value to distinguishing taxa (Johnson, Systematics of the new world species of *Marsilea* (Marsileaceae). Vol. 11. Systematic Botany Monographs. University of Michigan at Ann Arbor. 1986). Since no sporocarps were present in these Pulaski County populations, we had to rely on vegetative characters in making our identification.

Plants exhibiting two distinct growth forms were found during all three visits to the site: a short form growing on sandy-to-muddy substrate at the edge of the water with some plants entirely submerged and a taller form found on the bank above the water level. Heterophylly in amphibious plants is not uncommon and is exhibited in *Marsilea* by the phenotypic plasticity of the leaves resulting in distinct floating, submerged, or aerial (land) leaves (Johnson, Systematics of the new world species of *Marsilea* (Marsileaceae). Vol. 11. Systematic Botany Monographs. University of Michigan at Ann Arbor. 1986). Johnson (1986) reported that land leaves are smaller than aquatic leaves, though the opposite was observed at this site. The plants with the largest leaves, in excess of 20 cm tall, were found growing on dry land behind a partially submerged log along the edge of the water. The taller terrestrial plants had fewer leaves than the smaller aquatic ones.

Patch size ranged from isolated individual plants to dense clusters up to 20 m long and 3 m wide. 56.6% of the patches covered less than 1 m^2, 24.5% covered from 1 to 5 m^2, 13.2% covered from 5 to 10 m^2, and 5.7% covered from 10 to 20 m^2. A typical patch was shoreline linear, extending less than 1 m into the water but often twice as far onto the shore, depending on the slope of the bank. The area of greatest density fell within 0.5 m of the shore in either direction, with the plants farthest from the water's edge being fewer and more widely spaced. Patches on more steeply sloping banks were restricted to the shoreline more than patches on less steeply sloping banks. *Marsilea* was absent from flat areas along the shoreline, possibly excluded by abundant grasses. The plants were concentrated on the calm banks of the backwater ponds and gentle, meandering streams connecting these ponds to the river. Only one small patch of plants was found on the more turbulent river-side of the islands, and it was approximately 2.5 m up the bank from the waters edge. Associated genera were *Pluchea*, *Rotala*, *Polygonum*, *Sagittaria*, and several grasses.

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