PAST PRESIDENTS OF THE ARKANSAS ACADEMY OF SCIENCE

Charles Brooker, 1917  
Dwight M. Moore, 1932-33, 64  
Flora Haas, 1934  
H. H. Hyman, 1935  
L. B. Ham, 1936  
W. C. Munn, 1937  
M. J. McHenry, 1938  
T. L. Smith, 1939  
P. G. Horton, 1940  
I. A. Willis, 1941-42  
L. B. Roberts, 1943-44  
Jeff Banks, 1945  
H. L. Winburn, 1946-47  
E. A. Provine, 1948  
G. V. Robinette, 1949  
John R. Totter, 1950  
R. H. Austin, 1951  
E. A. Spessard, 1952  
Delbert Swartz, 1953  
Z. V. Harvalik, 1954  
M. Ruth Armstrong, 1955  
W. W. Nedrow, 1956  
Jack W. Sears, 1957  
J. R. Mundie, 1958  
C. E. Hoffman, 1959  
N. D. Buffalo, 1960  
H. L. Bogan, 1961  
Trumann McEver, 1962  
Robert Shideler, 1963  
L. F. Bailey, 1965  
James H. Fribourgh, 1966  
Howard Moore, 1967  
John J. Chapman, 1968  
Arthur Fry, 1969  
M. L. Lawson, 1970  
R. T. Kirkwood, 1971  
George E. Templeton, 1972  
E. B. Wittlake, 1973  
Clark McCarty, 1974  
Edward Dale, 1975  
Joe Guenter, 1976  
Jewel Moore, 1977  
Joe Nix, 1978  
P. Max Johnston, 1979  
E. Leon Richards, 1980  
Henry W. Robison, 1981  
John K. Beadles, 1982  
Robbin C. Anderson, 1983  
Paul Sarrah, 1984  
William L. Evans, 1985  
Gary Heidt, 1986  
Edmond Bacon, 1987  
Gary Tucker, 1988  
David Chittenden, 1989  
Richard K. Speairs, Jr., 1990  
Robert Watson, 1991  
Michael W. Rapp, 1992

INSTITUTIONAL MEMBERS

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

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

EDITORIAL STAFF

EDITOR: DR. HARVEY BARTON, Dept. of Biological Sciences, Arkansas State University, State University, AR 72467.

NEWSLETTER EDITOR: RICHARD A. KLUENDER, Dept. of Forest Resources, University of Arkansas at Monticello, Monticello, AR 71655.

BIOTA EDITOR: LEO J. PAULISSEN, Botany and Bacteriology Department, University of Arkansas, Fayetteville, AR 72701.

ASSOCIATE EDITORS:

AGRONOMY/PLANT PATHOLOGY: George E. Templeton (UA)  
PHYSICS: Mostafa Hemmati (Ark. Tech)  
WILDLIFE MANAGEMENT: Gary A. Heidt (UALR)  
ENGINEERING: Robert D. Engelken (ASU)  
Roger Hawk (UALR)  
MICROBIOLOGY: Larry Hinck (ASU)  
CHEMISTRY: Frank Setliff (UALR)

COVER: Queen snake, Regina septemvittata, from the Mulberry River, Crawford County, Arkansas. Photo by Stan Trauth.
In Memoriam:
Herman L. Bogan, 1907 - 1992

Herman L. Bogan passed away on November 15, 1992 at Eastwood Hospital in Memphis, Tennessee. He was a long-time member of the Arkansas Academy of Science and served as President in 1961.

The son of Charles Edgar Bogan and Lula Mae Westbrook Bogan, he was born in Paragould, Arkansas, the second of nine children. He attended Paragould High School where he lettered in football. His undergraduate work was done at Arkansas State College (now Arkansas State University) where he graduated in 1934 with a major in biology and minors in chemistry, economics and sociology. While in college, his interest in athletics continued and he lettered in football and track. He completed his master's degree in chemistry at the University of Arkansas in 1940 and throughout his career, he continued to work on his doctorate in chemistry at the University of Tennessee Medical Center in Memphis.

Professor Bogan began his teaching career in 1935 at Paragould High School where he served as science teacher, coach and principal. From there, he went to Little Rock Junior College where he taught chemistry from 1940 through 1957. In 1957, he accepted a teaching position in the Department of Chemistry at Arkansas State College, where he remained until 1964. Then, beginning in 1964, he joined the faculty at the University of Tennessee Medical Center where he taught chemistry and biochemistry until his retirement in 1972. He continued teaching for two private schools in Memphis until 1981.

His primary professional interests were science education and athletics. He refereed both football and basketball games from about 1940 to 1964. In 1961, the year he was President of the Academy, he was also President of the Arkansas Officials Association. The Arkansas Gazette made some references to this in the years following stating that he was the only person to head the state science and referees associations in the same year.

He is survived by his wife, Wordna, of Memphis; a daughter, Rose Mae, of Sylvania, Georgia; a son, John, of Memphis; four grandchildren; one brother; and six sisters.

I first met Herman in 1949, when I joined the faculty of Little Rock Junior College. He was extremely helpful to me, both in his willingness to help me as a greenhorn beginning a teaching career and as a personal friend. He was held in highest regard by faculty, staff and students for his integrity and competence along with the scope and depth of his friendship. With heartfelt respect, I offer that, in my opinion, there was a healthy mix of referee and colleague that permeated his life. Things were either "in bounds" or "out of bounds"...very few shades of gray in his thoughts or actions. He was deeply committed to his family, his church, his friends and his profession. We were privileged to know him. We will miss him.

James H. Fribouurgh
University of Arkansas at Little Rock
FIRST BUSINESS MEETING

28 members present

1. President Rapp called the meeting to order at 11:28 a.m. by calling attention to the available handouts (Treasurer’s report and Secretary’s copies of the minutes of last year’s Business Meetings).

2. Rapp recognized Robert Wright, Local Arrangements Chair, to introduce Dr. Winfred Thompson, President of UCA, who extended formal welcome of the Academy to the UCA campus. Dr. Thompson referred to widespread criticism of math and science competency levels and our obligation to respond to these criticisms. He also briefly referred to their bid for the new state math and science high school.

3. Rapp recognized Henry Robinson, Historian, who reported that this meeting is the fifth time on the UCA campus. Other meeting years were 1934, 1964, 1974 and 1983.

4. Rapp invited the members present to submit comments and/or corrections to the minutes of last year’s business meetings.

5. Rapp recognized Robert Wiley, Treasurer, who reported on the solid financial status of the Academy. Rapp asked about profit from the 1991 meeting, but there was none because of a miscommunication with the Arkansas Science Teachers Association, who were not advised of the extent of the expenses of using the facilities at the Continuing Education Center in Fayetteville Richard Speairs asked how widespread or systematic is the distribution of copies of the Proceedings to abstracting services. No precise figures were forthcoming, but general consensus agreed that our journal is being broadly abstracted.

### DISTRIBUTION OF FUNDS — as of 3 October 1992:

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### INCOME — Anticipated prior to Annual Meeting:

- Interest — Checking Account ($5.00 x 7) | $35.00
- Interest — Certificates of Deposit | $498.99
- Payment of 1992 dues — an estimate based on 1991 — (Reg. $840; Sust. $280; Spon. $60; Life $480; Assoc. $10) | $1745.00
- Institutional Memberships ($100.00 x 1) | $100.00
- Proceedings — Page Charges Vol 45 ($25.00 x 30.5) | $762.50

Total | $2129.49

### EXPENSES — anticipated prior to Annual Meeting:

- Newsletter ($50.00 x 2) | $100.00

Total | $20,992.97

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**Secretary’s Report**

**MINUTES OF THE SEVENTY-SIXTH MEETING — APRIL 1992**
6. Rapp recognized Harvey Barton, Editor of the Proceedings, who requested attendees to pick up their copies of the journal and campus representatives return with unclaimed copies destined for that campus. Sections chairs of paper presentations also need to pick up manuscripts from the presenters if publication is desired. Barton also explained the error Phillips Litho had made by placing the 1990 Table of Contents on the cover of the 1991 journal and that an erratum sheet will be available for distribution soon. Barton also moved (2nd: R. Speairs) that $500 be appropriated for editorial consulting for the 1992 volume (#46).

7. Rapp recognized Richard Kluender, Editor of the Newsletter, who explained his department's support of the production of the Newsletter and projected that if that support declined or ceased, the approximated cost to the Academy would be $800. He moved (2nd: J. Gaiser) that $800 be appropriated by the Academy to support the Newsletter in the event that departmental support ceases.

8. Rapp reported, on behalf of the Nominations Committee, that Walt Godwin (Chemistry, UAM), James Peck (Biology, UALR), and John Peck (Biology, UCA) had been submitted as candidates for Vice President. He called for nominations from the floor. None were made at this meeting.

9. Rapp recognized Art Johnson, Chair of Constitution Committee, to present proposed revisions to the Constitution. He did and moved (2nd: H. Robison) to accept these changes.

10. Rapp recognized Tom Lynch, Chair of Science Education Committee, to distribute copies of a proposed Position Statement, prepared by members of Project ADVISE, regarding proposed science curriculum changes for K-12. They are seeking the Academy's support of this position statement. Lynch moved (2nd: H. Barton) that the Academy support this statement. Lynch also announced presentations to be done in the Science Education Section of this meeting.

11. Rapp recognized John Peck, Director of Science Talent Search, who reported on the achievements of young Arkansas scientists at the national level. One student was a semi-finalist with a project in physics; others achieved third place and honorable mention with projects in immunology and math. Peck moved (2nd: J. Wear) that the Academy appropriate $150 to buy plaques and certificates for winners and their teachers.

12. Rapp recognized R. Wiley to read a letter from Ms. Pat Knighten, Director of the Junior Academy of Science. She expressed the need for assistance or replacement as director and issued a motion (2nd: R. Watson) for the appropriation of $250 to support the Junior Academy.

13. Rapp also recognized the functions of the State Science Fair and the eight regional divisions. He requested that Wiley also move (2nd: R. Mehta) that the Academy appropriate $400 to renew the Academy's support of the regional and state science fairs and send winning students to the international science and engineering fair. The appropriation will be divided equally among the eight regional science fairs. Rapp also recognized Rudy Timmerman, President of ASTA, and expressed appreciation that ASTA is meeting with us this year (second in succession), Rapp also submitted to the Secretary a tally of Junior Academy membership and activities for the past six years for possible inclusion in the minutes for information.

14. President Rapp asked for any other items of old business or committee reports. Hearing none, he continued with new business.

15. President Rapp announced the compositions of the Auditing Committee (Stan Truth, Chair), Awards Committee (John Peck, Chair), the Resolutions Committee (Gary Heidt, Chair).

16. Rapp recognized Robert Watson, who asked if a representative from Henderson State University was present. Receiving no response, Watson announced that HSU has invited the 1993 meeting of the Academy to their campus. The Executive Committee has accepted that invitation.

17. President Rapp announced that Pat Knighten, Director of the Junior Academy, would like to be replaced. Give any suggestions to Art Johnson (incoming President).

18. Rapp asked if a member of Sigma Xi from the Fayetteville Chapter was present to respond to a question about judging graduate student paper presentations. No response came, so the "local arrangements--awards committee" will handle all the judging.

19. Rapp recognized Robert Wright and the Local Arrangements Committee (Paul Krause, Harold Pry, David Dussourd, and Ken Freiley). Wright reported that there were no major changes in the paper sections and provided information on local eating establishments.

20. Rapp again recognized H. Barton who requested authors submit manuscripts for publication to section chairmen.

21. Rapp announced the location and time of the banquet and the banquet speaker, Lincoln Brower, whose topic will be on the life history of monarch butterflies.

22. President Rapp adjourned the first business meeting at 12:15 p.m.

SECOND BUSINESS MEETING

President Rapp called the meeting to order at 12:04 p.m.

1. Rapp asked for any additions/corrections to the minutes of last year's business meetings as distributed. Receiving none, he asked for a motion to approve (Rickett; 2nd: W. Godwin). Passed by voice vote.

2. Rapp reminded the membership of the Treasurer's 5 report and explanation. R. Wiley moved (2nd: A. Johnson) the acceptance of the report. A report from the Auditing Committee (Stan Truth and David Saugey) proved the Treasurer's records were appropriate and in order. H. Robison moved (2nd: R. Wright) the acceptance of the Auditing Committee's report. Passed. Treasurer's report was also accepted by voice vote.

3. Rapp then asked the Secretary to restate the series of motions asking for financial support initially made at the first business meeting (Barton: editorial consulting for Proceedings, vol. 46 [$500]; Kluender: Newsletter preparation [$800]; Peck: Science Talent Search [$150]; Wiley for P. Knighten: Junior Academy of Science [$250]; Wiley for Rapp: State Science Fall, Association [$400]). K. Beadles asked for the sum (= $2100). Beadles then moved (2nd: H. Robison) approval of these requests as a group. Passed.

Arkansas Academy of Science

S. Cent. Reg Fair 150 200 150 181 164 169
S. East Reg. Fair 135 125 125 115 124 100
S. West Reg. Fair 143 116 0 71 72 41
State Science Fair 243 248 199 229 219

Proceedings Arkansas Academy of Science, Vol. 46, 1992
4. Rapp recognized A. Johnson to present proposed changes in the Constitution. He also asked if anyone needed (and distributed) copies of the old or the "new" Constitution. Johnson explained the changes and recognized other committee members, George Harper and John Rickett. Two minor errors (the date should be corrected and the word "operate" be reinserted into section 13.a). The motion (made during the first business meeting) to accept the revisions passed, but in the process of voting, President Rapp pointed out that first-year members were not allowed to vote on Constitutional matters, and took the opportunity to have new members identify themselves. The revised and approved Constitution is attached as Appendix A.

5. President Rapp recognized the Nominations Committee (Mustafa Hemmati, Chair, Collis Geren, and Ed Bacon). Hemmati announced again and recognized the nominees for Vice President. No nominations came from floor; K. Beadles moved (2nd: R. Wiley) that nominations cease. Passed. Regular business and one runoff election James Peck to the office of Vice President. While voting progressed, President Rapp recognized life members of the Academy.

6. Rapp recognized the Resolutions Committee, and R. Speairs read the resolutions composed by them (Appendix B). Speairs moved (2nd: J. Guenter) acceptance. Two minor additions (Stan Truth was also moderator for the Vertebrate Zoology Section, and Cameron Dorey for Chemistry) were made, and the resolutions were accepted.

7. Rapp recognized M. Hemmati again to announce other nominations—Robert Wiley for Treasurer and Richard Klunder for Newsletter Editor. Additional nominations were called; none came. Walt Godwin moved (2nd: H. Robson) that nominations for Treasurer cease and Wiley be elected by acclamation. Motion passed. Robert Watson moved (2nd: R. Speairs) that nominations for Newsletter Editor cease and that Klunder be elected by acclamation. Motion passed.

8. President Rapp called for a representative from Henderson State University; getting no response, Rapp then deferred to Robert Watson to announce that HSU has been extended and accepted by the Executive Committee as the meeting site for 1993. Rapp also stated that invitations for the 1994 meeting site may be submitted to the Executive Committee.

9. Rapp then revisited and briefly explained and responded to some question regarding the intended content of the Post Session developed by individuals participating in Project ADVICE for formal approval. The motion to accept and support this document (made at the First Business Meeting) passed unanimously.

10. Rapp recognized John Peck to announce the student award winners. Jay Sims, Earth Science Department, UALR, won the Physical Science award with the paper, "Problems in the Detection and Delineation of a Contaminant Plume from a Leaking Underground Storage Tank." Brad Johnson, Biology Department, Hendrix College, won the Life Science award with the paper, "Fluorescein Angiography: An Effective Means of Assessing Reinal Vascular Pathology in Newborn Rats." Yau Kong Leong, Mechanical Engineering Department, UA, won the graduate student award with the paper, "Thin Film Mechanical Property Measurements Using Micromachined Structures." The two undergraduate awards were designated for the first time "Dwight Moore Undergraduate Research Awards." President Rapp chose this opportunity to recognize Ms. Clementine Moore in the audience in honor of Dwight Moore's contributions to the Academy.

11. Rapp passed out a roster of individuals who are involved in restructuring science curricula in the state department. Academy members were encouraged to contact any of these persons to catch dates and times of hearings to be held.

12. President Rapp announced, at the request of M. Mazummer (UALR) to announce the availability of minority scholarships in Engineering Technology of approximately $25,000.

13. Rapp then asked R. Wright to report on the attendance at this meeting. About 270 persons registered for this meeting.

14. Rapp asked for any other old business. R. Speairs issued a plea for the Academy members (individually) to support the ten or so technical colleges in Arkansas in their growth efforts, particularly as they prepare for accreditation.

15. President Rapp asked for new business:
   a. Rapp reported a message from Pat Knight, her work with the Junior Academy, and the absence of several regional directors. She would like to be replaced, and incoming President, Art Johnson, was charged with that responsibility.
   b. Rapp announced that ASTA is jointly meeting with us and encouraged Academy members to stay and participate in their sessions this afternoon.
   c. Rapp announced that unclaimed copies of the Proceedings be taken back to the various campuses and individually distributed to save mailing costs.
   d. Rapp announced that Historian, H. Robison, would still like to receive memorabilia items relating to the history of the Academy for a roving display.
   e. K. Beadles asked a question about the phrase "...higher order of thinking..." contained in the Position Statement. H. Barton opined that "critical thinking" was meant.
   f. President Rapp called for additional new business, none.

16. Rapp expressed appreciation to the Academy, particularly individual members with whom he had worked closely. He then recognized Art Johnson as the incoming President and passed the gavel to him. Johnson presented Rapp with a plaque of appreciation.

17. President Johnson asked the membership for ideas and help for reaching groups we are not currently reaching and progressing in directions we are not currently going. He pointed out the accessibility of the Executive Committee, which usually meets again in September or, if necessary, at any time the President chooses to call a meeting.

18. President Johnson then called for any new business. Hearing none, he adjourned the meeting at 12:53 p.m.

Respectfully submitted,

John Rickett, Secretary

MEMBERS 1992

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<td>Swayne A.</td>
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**Secretary's Report**

Proceedings Arkansas Academy of Science, Vol. 46, 1992
APPENDIX B
RESOLUTIONS

The members of the Arkansas Academy of Science express their
gratitude to the University of Central Arkansas at Conway for hosting
the 1992 meeting of the Arkansas Academy of Science. In particular,
thanks is given to the local arrangements committee: Robert Wright,
Chairman; Ken Freiley; Paul Krause; Harold Pray; David Dussourd; and
numerous UCA students. Appreciation is expressed for the use of
UCA’s outstanding facilities, hospitality, and excellent banquet. Also,
thanks is given to Lincoln Brower for his presentation on monarch
butterflies.

The Academy appreciates the efforts of the various section
chairpersons and recognizes the important role they played in the
conduct of the meeting. To be noted are: Mark Sutherland (Biomedical);
Joseph Lombardi (Invertebrate Zoology); John Choiniski and Ken
Freiley (Botany); Jerry Manion, Williams Taylor and Cameron Dorey
(Chemistry); Dean Hirschi and Rahul Mehta (Physics, Math,
Engineering, and Geology); Heather Woolverton (Physics and
Geology); Stephen Addison (Science Education); John Rickett (Aquatic
and Environmental Biology); Steven Runge (Microbiology and
Molecular Biology); Al Karlin and Stan Trauth (Vertebrate Zoology).

The Academy expresses gratitude to the various directors of the
science youth activities which are supported by the Academy: Tom
Lynch (Chair, Science Education Committee); Mike Rapp (Director,
Arkansas State Science Fair); Tom Palko (Director, Junior Science and
Humanities Symposium); John Peck (Science Talent Search) and Pat
Knighten (Arkansas Junior Academy of Science).

The Academy is only as successful as its leadership in planning,
working, and directing the various activities. To Mike Rapp (President),
Art Johnson (President-Elect), George Harp (Vice President), John
Rickett (Secretary), Robert Wiley (Treasurer) Robert Watson (Past
President), Harvey Barton (Appointments Editor) Dick Kluender
(Newsletter Editor), and Henry Robison (Historian), the Academy
expresses its profound gratitude for an excellent year. In addition, the
Academy wishes to express its appreciation to all of those individuals
who have contributed their time and efforts by serving on the various
committees of the Academy.

Finally, the Academy congratulates all of those who presented papers,
most especially the student presenters, which have provided for the
success of this meeting as well as science education and research in
Arkansas.

Gary A. Heidt
Richard K. Speairs, Jr.
Thomas L. Foti
PROGRAM
Arkansas Academy of Science
Seventy-Sixth Annual Meeting
3-4 April, 1992
University of Central Arkansas at Conway

Friday, 3 April, 1992

Registration
Executive Committee
First Business Meeting
Exhibits and Refreshments

Paper Sessions

Biomedical
Invertebrate Zoology
Botany
Chemistry: Analytical, Inorganic and Physical
Physics, Math, Engineering, Geology

Banquet
Speaker: Dr. Lincoln Brower
*The Grand Saga of the Monarch Butterfly*

Saturday, 4 April, 1992

Registration
Exhibits and Refreshments
Second Business Meeting

Paper Sessions

Chemistry: Organic, Biochemistry
Physics, Geology
Science Education
Aquatic and Environmental Biology
Vertebrate Zoology
Microbiology and Molecular Biology
SECTION PROGRAMS
[* = Student Paper]

Friday, April 2, 1991

BIOMEDICAL
Chairman: Mark V. Sutherland, Hendrix College

THE EFFECTS OF BACTERIAL LIPOPOLYSACCHARIDE ON PLASMA CORTICOSTEROIDE CONCENTRATIONS AND BODY TEMPERATURES OF NEW ZEALAND RABBITS (ORYCTOLAGUS CUNICULUS).

Wilkins, P.K., S.N. David and L.W. Hinck, Department of Biological Sciences, Arkansas State University, P.O. Box 599, State University, AR 72467-0599.

THE EFFECT OF BACTERIAL LIPOPOLYSACCHARIDE-INDUCED FEVER ON THE HUMORAL RESPONSE OF NEW ZEALAND WHITE RABBITS.

Lawrence W. Hinck and Stanley N. David, Department of Biological Sciences, Arkansas State University, State University, AR 72467-0599.

IN-VIVO SPECTROSCOPIC AND IMAGING STUDIES OF PHOTOSENSITIZERS IN PHOTODYNAMIC THERAPY.


ENHANCEMENT OF ANTIGEN-SPECIFIC ANTIBODY SECRETION BY INTERFERON.

Tony E. Caver, J. Mitchell Winkler, Karen E. Eckles (Mark V. Sutherland), Department of Biology, Hendrix College, Conway, AR 72032.

*INTERFERON-STIMULATED ANTIBODY SECRETION FROM CHEMICALLY SUPPRESSED RABBIT SPLEEN CELLS.

J. Mitchell Winkler, Tony Caver, Karen Eckles, Mark Sutherland, Biology Department, Hendrix College, AR 72032.

THE EFFECT OF GRIFFONIA SIMPLIFICOLIA-I-B4 ON THE PRODUCTION OF INF-6 BY HUMAN MONOCYTES.

David H. Holley, (Mark Sutherland), Biology Department, Hendrix College, Conway, AR 72032.

*METHODS FOR DETECTING ANTIMICROBIAL ACTIVITY IN LYMPHOID CELL CULTURES.

Karen E. Eckles, Tony E. Caver, J. Mitchell Winkler, (Mark Sutherland), Department of Biology, Hendrix College, Conway, AR 72032.

*HYPOTHYROIDISM AND METABOLISM OF OMEGA SIX POLYUNSATURATED ESSENTIAL FATTY ACIDS.

Sylvia Hill and Lawrence M. Mwasi, Department of Biology, University of Arkansas at Pine Bluff, Pine Bluff, AR 71601.

OXAZOLIDINES AS POTENTIAL PRODRUGS.

Bridgette Samuels and Richard B. Walker, Chemistry Department, University of Arkansas at Pine Bluff, Pine Bluff, AR 71601.

EXTRACTION OF OIL IN A DEPENDENT METABOLISM OF ACETAMINOPHEN.


*ALTERATION BY ANGUINE OF THE ANTIPROLIFERATIVE EFFECTS OF CISPLATIN, 5-FLUORO-URACIL, AND VINCRISTINE IN HUMAN MULTIPLE TRANSITIONAL CELL CANCER CELLS (253) IN VITRO.

Angela W. Davis, Clifton Orr, and Mattie G. Glover, Department of Biology, University of Arkansas at Pine Bluff, Pine Bluff, AR 71601.

*FLUORESCIN ANGIOGRAPHY: AN EFFECTIVE MEANS OF ASSESSING RETINAL VASCULAR PATHOLOGY IN NEWBORN RATS.

Brad D. Johnson and John S. Penn, Arkansas Center for Eye Research, University of Arkansas for Medical Sciences, Little Rock, AR 72205.

THE EFFECT OF PHENCYCLIDINE (PCP) METABOLITE COVALENT BINDING ON PCP STEADY-STATE CLEARANCES IN SPRAGUE-DAWLEY RATS.

S. Michael Owens and Mark A. Zorbas, Department of Pharmacology and Toxicology, University of Arkansas for Medical Sciences, Little Rock, AR 72205.

INVERTEBRATE ZOOLOGY
Chairman: Joseph R. Lombardi, Hendrix College

A SYNOPSIS OF THE GENUS TROPISTERNUS IN ARKANSAS.

George L. Harp and Walter H. Neasbitt, Department of Biological Sciences, Arkansas State University, State University, AR 72467.

NEW RECORDS OF ARKANSAS ODONATA.

Phoebe A. Harp and George L. Harp, Department of Biological Sciences, Arkansas State University, State University, AR 72467.

A CHECK-LIST OF THE LYCOIDEAE AND GNAPHRIDEAE OF ARKANSAS.

Sharon Burris and Peggy Rae Dorris, Henderson State University, Box 7544, Arkadelphia, AR 71999-0001.

THE OCCURRENCE OF POISONOUS SPIDERS IN ARKANSAS.

Peggy Rae Dorris, Henderson State University, Box 7544, Arkadelphia, AR 71999-0001.

MASS ENTRAPMENT OF APHIDS IN LETTUCE LATEX.

David E. Dussourd, Department of Biology, University of Central Arkansas, Conway, AR 72035.

ECOLOGY AND SUCCESSION OF CARRION INSECTS.

Kelly K. Agnew, (Joseph R. Lombardi), Biology Department, Hendrix College, 1601 Harkrider, Conway, AR 72032.

HEMATOZOA OF COMMON GRACKLES, QUISCALUS QUISCULA (LINNAEUS).

Arthur A. Johnson, Hendrix College, Conway, AR 72032.

BOTANY
Chairman: John S. Choiinski, Kenneth J. Freiley, University of Central Arkansas

*NECTAR PRODUCTION AND THE POLLINATION BIOLOGY OF TWO SPECIES OF FLOWERING VINES.

Michael D. Warriner, Jill M. Gregory, and William H. Baltosser, Department of Biology, University of Arkansas at Little Rock, Little Rock, AR 72204.

*NECTAR PRODUCTION AND THE POLLINATION BIOLOGY OF TWO SPECIES OF LOBELIA.

Jill M. Gregory, Michael D. Warriner, and William H. Baltosser, Department of Biology, University of Arkansas at Little Rock, Little Rock, AR 72204.
**G+C RATIO IN TALL FESCUE DNA AS MEASURED BY MELTING POINT CURVES.**
Robbin G. Lone, Alvan A. Karlin, Department of Biology, University of Arkansas, Little Rock, AR 72204, and R. Marty Roop, Department of Microbiology, University of Arkansas for Medical Sciences, Little Rock, AR 72205.

**GREEN TREEFROGS AND GRASSHOPPERS AS VECTORS FOR DISPERAL OF COLLETOTRICUM GLOEOSPORIOIDES.**
G. Moore, X.B. Yang, and D.O. TeBeest, Department of Plant Pathology, 171 Plant Science Building, University of Arkansas, Fayetteville, AR 72701.

**GENETIC UNIFORMITY WITHIN ARKANSAS POPULATIONS OF THE THREATENED SHRUB NIEVUSIA ALABAMENSIS (ROSACEAE), ALABAMA SNOW WREATH.**
Kenneth J. Freiley, Biology Department, University of Central Arkansas, Conway, AR, 72035.

**OPTIMUM CONE COLLECTION PERIOD IN ARKANSAS FOR ESTABLISHING POLYEMBRYOGENESIS IN Loblolly Pine.**
J.M. Al-Khayri, F.H. Huang, and H.T. Zhang, Department of Horticulture and Forestry, University of Arkansas, Fayetteville, AR 72701.

**AN ASSESSMENT OF TIMBER RESOURCE VALUES IN ARKANSAS.**
Williams, R.A. and R.A. Klauder. University of Arkansas at Monticello, Department of Forest Resources, P.O. Box 3468, Monticello, Arkansas, 71655.

**EFFECT OF WATER STRESS ON SEEDLING GROWTH OF THE LOWLAND AFRICAN SAVANNA TREE, COLOPHOSPERMUM MOPANE.**
John S. Choinski, Jr., Department of Biology, University of Central Arkansas, Conway, AR 72035.

**WATER USE EFFICIENCY COMPARED WITH DROUGHT TOLERANCE IN RICE.**

**MEASURING SHRUBLAND VEGETATIONAL STRUCTURE USING AVIAN HABITATS AS AN EXAMPLE.**
Douglas A. James, Department of Biological Sciences, University of Arkansas, Fayetteville, AR 72701.

**CHEMISTRY: ANALYTICAL, INORGANIC, AND PHYSICAL.**
Chairman: Jerry M. Manion, University of Central Arkansas

*THE USE OF A SPUTTERING ION SOURCE IN THE STUDY OF GAS PHASE TRANSITION METAL ION CHEMISTRY.*
William R. Everett, William S. Taylor, Department of Chemistry, University of Central Arkansas, Conway, AR 72035.

*ANALYSIS AND REMOVAL OF HEXACHLOROBENZENE IN ENVIRONMENTAL SAMPLES.**

*LIQUID AND SOLID PHASE TELLURIZATION OF ELECTROPLATED CADMIUM FILMS METAL INTO CADMIUM TELLURIDE.*
Robert Engelken, Charles Brinkley, Kwok Fai (Larry) Yu, and Lip Ngin (Steward) Chang, Arkansas State University, Department of Engineering, P.O. Box 1740, State University, AR 72467.

*PHOTOMODULATED CONTRAST AND IMAGING OF ELECTROPLATED SEMICONDUCTOR FILMS.*
Robert Engelken, Charles Brinkley, Kwok Fai (Larry) Yu, and Lip Ngin (Steward) Chang, Arkansas State University, Department of Engineering, P.O. Box 1740, State University, AR 72467.

**SCF-MO AND MONTE CARLO CALCULATIONS OF POLY (DIMETHYLSILOXANE).**
Shannon H. Brownfield and Jerry A. Darsey, Department of Chemistry, University of Arkansas at Little Rock, Little Rock, AR 72204.

**INHIBITION OF PROTEOLYTIC ENZYMES BY LEUPEPTIN ANALOGS.**
Wanda Jones and Rose McConnell, Department of Chemistry, University of Arkansas at Pine Bluff, Pine Bluff, AR 71601.

**ELECTROCHEMISTRY OF SOME NITRO-PHENYLFLURANS.**
Himansu J. Vyas, Ali U. Shaikh, Department of Chemistry, University of Arkansas at Little Rock, Little Rock, AR 72204, and E. Kim Fifer, Department of Biopharmaceutical Sciences, University of Arkansas for Medical Sciences, Little Rock, AR 72205.

**DESIGN AND PERFORMANCE OF A VARIABLE WAVELENGTH FLAME INFRARED EMISSION DETECTOR FOR GAS CHROMATOGRAPHY.**
Weigun Zhang and M. Keith Hudson, Department of Electronics and Instrumentation, University of Arkansas at Little Rock, Little Rock, AR 72204.

**INFRARED-ABSORPTION PROPERTIES OF EL2 AND CARBON GAAS.**
Ja Zheng, University of Arkansas at Little Rock, Department of Electronics and Instrumentation, 2801 S. University, Little Rock, AR 72204.

**MODEL FOR THE CO POISONING OF HYDRODESULFURIZATION CATALYSTS. SYNTHESIS AND STRUCTURE OF [Ru(CO)(PPH3SCLH2)2Cl] + 2CHLBR.**
Mark Draganjac, Thomas B. Rauchfuss, School of Chemical Sciences, 350C Noyes Lab, Box 21, 505 S. Mathews Ave., Urbana, IL 61801, and Arnold L. Rheingold, Department of Chemistry, University of Delaware, Newark DE 19716.

**USE OF CAPILLARY ZONE ELECTROPHORESIS TO FOLLOW THE DEGRADATION OF BENZYLPEICILLIN IN STOMACH ACID.**
Susan Arrowood and A.M. Hoyt, Jr., Department of Chemistry, University of Central Arkansas, Conway, AR 72035.

**DETERMINATION OF CIMETIDINE IN URINE BY CAPILLARY ZONE ELECTROPHORESIS.**
Susan Arrowood and A.M. Hoyt, Jr., Department of Chemistry, University of Central Arkansas, Conway, AR 72035.

**SYNTHESIS AND CHARACTERIZATION OF TWO MIXED ESSENTIAL METALLOELEMENT SALICYLATES.**
Wilfred M. Willingham and William M. Willingham, Department of Chemistry, University of Arkansas at Pine Bluff, Pine Bluff, AR 71601.

**STRUCTURAL EVIDENCE OF A MONOMERIC COPPER (II) BENZOATE PYRIDINE COMPLEX [Cu(II)(C6H4O)(C5H4N)].**
Elise Williams, Shaheen Khan, and William M. Willingham, UABP Research Center, University Drive, Pine Bluff, AR 71601.

**PHYSICS, MATH, ENGINEER, GEOLOGY**
Chairman: Dean C. Hirschi, and Rahul Mehta
University of Central Arkansas

**FORECASTING WITH ARTIFICIAL NEURAL NETWORKS.**
S. Malasri, L.Y. Lin, and P. Orono, Christian Brothers University, Memphis, TN 38104.
LEAST-SQUARES POLYNOMIAL FILTERS.
D.G. Sam Synder, Department of Mathematics and Physics. University of Arkansas at Monticello, Monticello, Arkansas, 71655.

A MULTIPLE SAMPLE CRYOSTAT FOR THE DETERMINATION OF SUPERCONDUCTOR PROPERTIES.
By Burnside, R.M. Hawk, P.C. McLeod, Department of Electronics and Instrumentation, University of Arkansas at Little Rock, Little Rock, AR 72204.

ELECTROSTATIC GRANULAR FILTER. SONGPING GAO.
Kevin Tennal, and Malay Mazumder, Department of Electronics and Instrumentation, University of Arkansas at Little Rock, 2801 S. University Ave., Little Rock, AR 72204.

SYNTHETIC MULTIGATE DOPPLER SYSTEM.
Reagan Cole and Al Adams, University of Arkansas at Little Rock, Electronics and Instrumentation Department, 2801 S. University Ave., Little Rock AR 72204.

REAL TIME MULTIPLE PARTICLE AERODYNAMIC SIZE AND CHARGE MEASUREMENTS BY PARTICLE MOTION IMAGE ANALYSIS.
Charles Mu and Malay K. Mazumder, Department of Electronics and Instrumentation, University of Arkansas at Little Rock, 2801 S. University Ave., Little Rock, AR 72204.

*EXTERNAL CAVITY STRONG FEEDBACK FREQUENCY TUNABLE SEMICONDUCTOR LASERS.
Haiyin Sun, Department of Electronics and Instrumentation, University of Arkansas at Little Rock, 2801 S. University Ave., Little Rock AR 72204.

*APPLICATION OF STABLE OPERATING CRITERION TO STRONG EXTERNAL FEEDBACK SEMICONDUCTOR LASERS.
Haiyin Sun, Department of Electronics and Instrumentation, University of Arkansas at Little Rock, 2801 South University Avenue, Little Rock, AR 72204.

*THREE-DIMENSION MODELING OF THE EFFECT OF ATMOSPHERIC AEROSOLS ON THE GLOBAL TEMPERATURE.
Haiyin Sun and Malay K. Mazumder, Department of Electronics and Instrumentation, University of Arkansas at Little Rock, 2801 S. University Ave., Little Rock, AR 72204.

*THE EVALUATION OF A PISE LINEAR ARRAY AS AN INEXPENSIVE INFRARED LINE SCAN Camera SENSOR.
Jason Willis, Reagan Cole, David Wankum, and M. Keith Hudson, Department of Electronics and Instrumentation, University of Arkansas at Little Rock, Little Rock, AR 72204.

*MEASUREMENT OF THE COEFFICIENT OF THERMAL EXPANSION OF SUPERCONDUCTING THIN FILMS USING POWDER X-RAY DIFFRACTION.
Biju Chandran, R.C. Goforth and S. Nasrazadani, Department of Mechanical Engineering, University of Arkansas, Fayetteville, AR 72701.

*THIN FILM MECHANICAL PROPERTY MEASUREMENTS USING MICROMACHINED STRUCTURES.
Yau Kong Leong and R. Calvin Goforth, University of Arkansas, Mechanical Engineering Department, Fayetteville, AR 72701.

*DEVELOPMENT OF MOUND MUDS IN A MIXED SILICICLASTIC/ CARBONATE ENVIRONMENT.
John M. Ryan, Doy L. Zachey, Department of Geology, University of Arkansas, Fayetteville, AR 72701.

Saturday, April 4, 1992

CHEMISTRY: ORGANIC, BIOCHEMISTRY
Chairman: William S. Taylor, University of Central Arkansas

4-SUBSTITUTED ANILIDES OF 2,6- AND 5,6-DICHLORONITRILE POTENTIAL AGRICULTURAL AGENTS.
Frank L. Setliff and Nikhil G. Soman, Department of Chemistry, University of Arkansas at Little Rock, Little Rock, AR 72204.

HAMMETT CORRELATIONS IN THE ^H NMR SPECTRA OF SOME N-ARYLDIHALONICOTINAMIDES.
Frank L. Setliff, Nikhil G. Soman, Jody Z. Caldwell and Debra L. Rogers, Department of Chemistry, UALR, Little Rock, AR 72204.

A PHOSPHOROUS-31 NMR STUDY OF THE COMPETITION FOR THE PREFERENTIAL BINDING OF Lr, Mg*, AND Na* TO ATP IN AQUEOUS SOLUTIONS.
Susan G. Brown and Roger M. Hawk, Electronics and Instrumentation Department, University of Arkansas at Little Rock, 2801 S. University Ave., Little Rock, AR 72204, and Richard A. Komoroski, Departments of Radiology and Pathology, University of Arkansas for Medical Sciences, Little Rock, AR 72205.

*SYNTHESIS OF LEUPEPTIN ANALOGS FOR PROTEINASE INHIBITION.
Melanie Frazier and Rose McConnell, Department of Chemistry, University of Arkansas at Pine Bluff, Pine Bluff, AR 71601.

*SYNTHESIS AND PEPSTIN INHIBITION OF PEPSTATIN ANALOGS.
Anissa Evans and Rose McConnell, Department of Chemistry, University of Arkansas at Pine Bluff, Pine Bluff, AR 71601.

*OXAZOLIDINES DERIVED FROM EPHEDRINE AS POTENTIAL PRODRUGS.
Bridgette Samuels, Henri Linton, Jr., Lawrence Fitz and Richard Walker, Department of Chemistry, University of Arkansas at Pine Bluff, Pine Bluff, AR 71601.

*SYNTHESIS AND MUTAGENICITIES OF 3-SUBSTITUTED AND 3,5-DISUBSTITUTED 4-NITROPHENYLURANS.
E. Kim Fifer and Robert M. Freeeze, University of Arkansas for Medical Sciences, Little Rock, AR 72205; Ali Shaiik, Department of Chemistry, University of Arkansas at Little Rock, Little Rock, AR 72204; and J.P. Freeman, National Center for Toxicological Research, Jefferson, AR 72079.

*AQUEOUS RING-OPENING METATHESIS POLYMERIZATION OF 7-OXANORBORNENE SYSTEMS.
Tito Viswanathan and Jagdish Jethmalani, Department of Chemistry, University of Arkansas at Little Rock, Little Rock, AR 72204.

*EFFECT OF EPHEDRINE ISOMERS ON LOCOMOTOR ACTIVITY IN RATS.
Lawrence Fitz, Henri Linton, Jr., Bridgette Samuels and Richard Walker, Chemistry Department, University of Arkansas at Pine Bluff, Pine Bluff, AR 71601.

*TESTED OVERHEAD PROJECTOR DEMONSTRATIONS FOR HIGH SCHOOL CHEMISTRY.
Linus E. Moss and J.E. Bennett, Arkansas State University, Department of Chemistry, P.O. Box 419, State University, AR 72467.

THE SYNTHESIS OF SULFONAMIDE DERIVATIVES OF SALICYLIC ACID.
Irat J. Chowdhury, Richard B. Walker, Sheltor Fitzpatrick, J.P. Freeman, and William M. Williams, Research Center, University of Arkansas at Pine Bluff, Pine Bluff, AR 71601; Biology Department, University of Arkansas at Pine Bluff, Pine Bluff, AR 71601;
and National Center for Toxicological Research, Jefferson, AR 72079.

PHYSICS AND GEOLOGY
Chairman: Heather L. Woolverton, University of Central Arkansas

*COMPUTED GRAPHERICAL REPRESENTATIONS OF THE
GREGORIAN CALENDAR.
Stephen R. Addison and Lee Ann Criswell, Department of Physics,
University of Central Arkansas, Conway, AR 72035.

*VISUALIZING ELECTROSTATIC PHENOMENA USING
MATHEMATICA.
Eric Mayes, Department of Physics, Arkansas State University, State
University, AR 72467.

*PROBLEMS IN THE DETECTION AND DELINEATION OF A
CONTAMINATE PLUME FROM LEAKING UNDERGROUND
STORAGE TANK.
Jay Sims, Department of Earth Science, University of Arkansas at
Little Rock, 2801 S. University Ave., Little Rock, AR 72204.

*COMPARISON OF TWO MODELS FOR BREAKDOWN WAVES.
Debra Burris, Arkansas Tech University, 403 N. Cumberland Apts.
"C", Russellville, AR 72801 and Mostafa Hemmati, Arkansas Tech
University, Physics Department, Russellville, AR 72801.

EVALUATION OF ANISOTROPY OF HYDRAULIC CONDUCTION
IN A FRACTURED BEDROCK AQUIFER USING
STATISTICAL ANALYSIS METHODS.
D. Michelle Williams, Department of Earth Science, University of
Arkansas at Little Rock, 2801 S. University Ave., Little Rock, AR
72204.

VERTEBRATE FOSSILS FROM THE SARATOGA CHALK
(CAMPANIAN) OF SOUTHWESTERN ARKANSAS.
John T. Thurmond, Department of Earth Science, University of
Arkansas at Little Rock, 281 S. University, Little Rock, AR 72204.

COMPUTER MODELS OF EARTH'S MAGNETOSPHERE.
Dean Hirschi, Department of Physics, University of Central
Arkansas, Conway, AR 72035.

THE SCHROEDINGER EQUATION WITH SPHERICALLY
AVERAGED POTENTIALS.
C.A. Hughes, Arkansas State University, Department of Physics,
P.O. Box 70, State University, AR 72467.

TECHNIQUES FOR EFFICIENCY CALIBRATION OF PHOTON
DETECTORS FOR X-RAYS AND LOW ENERGY GAMMA RAYS.
Rahul Mehta, Department of Physics, University of Central
Arkansas, Conway, AR 72035.

SCIENCE EDUCATION
Chairman: Stephen R. Addison,
University of Central Arkansas

ON THE USE OF A TELESCOPE SIMULATOR TO TEACH
ASTROPHYSICS AND INSTRUMENTATION IN ASTRONOMY.
Stephen R. Addison, Department of Physics, University of Central
Arkansas, Conway, AR 72035.

WHAT RESEARCH SAYS TO THE SCIENCE TEACHER.
Delena Tull, Department of Biology, University of Central Arkansas,
105 Lewis Science Center, Conway, AR 72035.

BIOTECHNOLOGY CURRICULUM DEVELOPMENT FOR UNDER-
GRADUATE BIOLOGY.
Maurice G. Kleve, Dennis A. Baeyens, Alvan A. Karlin, Thomas J.
Lynch and James H. Peck, Department of Biology, University of
Arkansas at Little Rock, Little Rock, AR 72204.

CRITICAL THINKING WITH BOTANY: USE OF ALIEN LIFE
FORMS (ALFS) AS TEACHING EXEMPLARS.
James H. Peck, Department of Biology, University of Arkansas at
Little Rock, Little Rock, AR 72204.

ARKANSAS MATH CRUSADE.
Dr. Frank James, Department of Mathematics, University of
Arkansas at Pine Bluff, Pine Bluff, AR 71601.

COLLABORATIVE LEARNING IN DESIGN COURSES.
Robert L. Douglas, Memphis State University, Memphis, TN 38152.

IMPACT - PHASE II TECHNOLOGY BASED PROGRAM IN K-12
EDUCATION.
Cecil W. McDermott, IMPAC Learning Systems, Inc., 501
Woodlane Drive, Suite 122, Little Rock, AR 72201.

THE ARKANSAS SCHOOL FOR MATHEMATICS AND SCIENCE:
A STATUS REPORT.
John W. Ahlen, Arkansas Science and Technology Authority, 100
Main Street, Suite 450, Little Rock, AR 72201.

PROJECT ADVISE (ALLIANCE FOR THE DEVELOPMENT OF THE
VISION AND INITIATIVE FOR SCIENCE EDUCATION IN
ARKANSAS).
Jannie Huffman, Department of Chemistry, Arkansas State
University, State University, AR 72450.

AQUATIC AND ENVIRONMENTAL BIOLOGY
Chairman: John D. Rickett, University of Arkansas at Little Rock

CHARACTERIZATION OF BENTHIC COMMUNITIES OF LEAST
DISTURBED STREAMS IN ARKANSAS' ECOREGION.
Roland E. McDaniel, FTN Associates, Ltd., 3 Inwood Circle, Suite
220, Little Rock, AR 72211.

LABORATORY SURROGATE OR REAL WORLD CHARAC-
TERIZATION: TOXICITY TESTING VS. RAPID BIOASSESSMENT.
R.E. McDaniel, FTN Associates, Ltd., Little Rock, AR 72211 and
A.D. Price, Arkansas Department of Pollution Control and Ecology,
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8001 National Drive, Little Rock, AR 72209; and Roland E.
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OPTIMUM CONE COLLECTION PERIOD IN ARKANSAS FOR ESTABLISHING IN VITRO CULTURES OF LOBLLOLLY PINE (PINUS TAEDA L.)

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ABSTRACT

This study was conducted to determine the optimum period to collect loblolly pine (Pinus taeda L.) cones that contain embryos with the greatest capacity to produce embryogenic callus for establishing somatic embryogenesis. Cones were collected from trees at the University of Arkansas Agricultural Experiment Station, Fayetteville, in 1991 during four consecutive months: May, June, July, and August. Seeds were extracted and disinfected in 70% ethanol for 1 min, 50% Clorox for 20 min, followed by four water rinses. Seed coats were removed, and embryos were cultured on DCR medium adjusted to pH 5.7 and supplemented with 3 mg/L 2,4-D, 0.5 mg/L 6-BAP, 30 g/L sucrose, and 6 g/L agar. Callus was induced and maintained in the dark at 20 ± 5 C. Embryos collected in May failed to proliferate; however, 55%, 88%, and 66% of the embryos cultured produced callus from June, July, and August collections, respectively. Suspension cultures were initiated from pine callus and maintained for over 6 months in MSG medium for subsequent investigation of the conversion of embryogenic complexes into mature embryos and eventually into plantlets. Evidence for embryogenesis was observed with double-staining techniques.

INTRODUCTION

Tissue culture technology is recognized as an important means for rapid vegetative propagation, forest improvement, and increase in productivity (Karmosky, 1981; Farquhar et al., 1983; Haisig et al., 1987). Haasain et al. (1986) explained that to fully utilize tissue culture methods for forestry, the development of micropropagation methods from juvenile and mature tissue of commercially important conifers must be achieved before commercialization of forest tree micropropagation. Another important priority is the development of improved techniques for micropropagation and somatic embryogenesis including research toward a better understanding of the biochemical and developmental basis of plant regeneration from cell and tissue culture. Loblolly pine (Pinus taeda L.) is an economically important coniferous species in forests of the southeastern United States, and it is the main species growing on about 12 million hectares of plantations (Brenden et al., 1981). Research with tissue culture of loblolly pine has been the focus of several investigators (Gupta and Durzan, 1987a, 1987b; Gupta et al., 1987, 1988; Becwar et al., 1988; Becwar and Feirer, 1989; Durzan, 1988; Teasdale et al., 1986). Although embryogenic callus of loblolly pine can be induced, conversion of the immature somatic embryos to the mature somatic embryos and the recovery of plantlets remains difficult (Becwar and Feirer, 1989). Becwar et al. (1988) stated that the explant developmental stage is the most important factor for the initiation of embryogenic callus from loblolly pine immature embryos. The developmental stage is dependent upon the time the cones are collected for explant extraction. Because of regional differences in the developmental stage due to climatic differences, it is essential to define the optimum date (developmental stage) in our region to collect cones that will initiate embryogenic callus. Our goal was to evaluate the effect of this factor on explants obtained from Arkansas-grown loblolly pine trees.

The objectives of the present study were 1) to determine the climatic effect on the formation of callus, namely to identify the optimum period for collecting pine cones that would produce embryogenic callus and 2) to establish and maintain cell suspension cultures from this callus for conducting year-round research focused on the improvement of somatic embryogenesis, particularly to circumvent the problem associated with the availability of viable immature embryos, which may be restricted to a short period of the year.

MATERIALS AND METHODS

CONE COLLECTION

Loblolly pine cones were collected from the end of branches of four trees grown at the Arkansas Agricultural Experiment Station, Fayetteville, Arkansas. During 1991, four collections were made at the end of May, June, July, and August. Four cones were collected from each tree providing 16 cones at each collection. The 16 cones, however, were mixed as a way of randomizing the samples.

SEED EXTRACTION, DISINFECTION, AND EMBRYO REMOVAL

Scales were removed by peeling them away from the axis of the cone with a knife. The seeds were removed after being exposed, placed in a plastic bag, and kept in a refrigerator (4 C) for several days until all the seeds from the sample were extracted. The seeds were surface disinfected in 70% ethanol for 1 min, followed by immersion for 20 min in 50C Clorox solution containing 0.01% Tween 20, and rinsed four times in sterile water. Seed coats were removed with a scalpel to expose the immature embryos.

CALLUS INDUCTION

The embryos were cultured individually in culture tubes (16x100 mm) containing 5 ml of DCR medium (Gupta and Durzan, 1985) supplemented with 3 mg/L 2,4-dichlorophenoxyacetic acid (2,4-D), 0.5 mg/L benzylaminopurine (BAP), and 30 g/L sucrose, solidified with 6 g/L agar, and adjusted to pH 5.7. Callus was induced and maintained in the dark at 20 ± 5 C. The cultures were maintained by transfer to fresh medium at 4-week intervals.

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Optimum Cone Collection Period In Arkansas for Establishing In Vitro Cultures of Loblolly Pine (Pinus taeda L.)

CELL SUSPENSION ESTABLISHMENT AND MAINTENANCE

Suspension cultures were initiated from pine callus by cutting the callus into 1- to 2-mm pieces and placing 0.25 g of callus per 125-ml flask containing 25 ml of liquid MSG medium (Becwar et al., 1988). The medium was supplemented with 0.5 mg/L BAP, 0.5 mg/L kinetin, and 1 mg/L 2,4-D. The cultures were maintained by shaking at 100 rpm in darkness and subcultured at 2-week intervals. Callus from suspension cultures was retrieved after a month of culturing in liquid medium and cultured for 4 weeks on a medium solidified with 6 g/L agar to interrupt continuous culturing in liquid medium.

REDIFFERENTIATION OF CALLUS

To induce redifferentiation of the callus into somatic embryos, the callus was transferred to solid MSG medium supplemented with 0.5 mg/L kinetin, 0.5 mg/L BAP, and 0.2 mg/L 2,4-D. Callus cultured on this medium was kept in the dark for 4 weeks and then transferred to the light (50 μE/m²/s). The cultures were transferred to fresh medium every 2 to 3 weeks.

CYTOCHEMICAL STAINING

Staining procedures used were after Gupta and Durzan (1987a). Samples obtained from cell suspension, which contained cells and cell aggregates, were stained in 2% aceticarmine by mixing 1:1 (v/v) of cells and aceticarmine and heating slightly for 15 s. This stain was filtered out, and the tissue was stained again in 0.5% Evans’ blue, also at 1:1 (v/v) ratio. Excess of stain was removed by washing the tissue in liquid medium, and to increase optical clarity of the cells, 100% glycerol was added. The double-stained cells were observed through an inverted microscope, and microphotographs were obtained.

RESULTS AND DISCUSSION

CALLUS INDUCTION

The number of seeds collected per cone was variable, ranging from about 10 to 30 seeds. From each collection period, 200 seeds were used. Immature embryos collected in May failed to proliferate callus. These early collected seeds had soft seed coats, which may have promoted the penetration of the disinfectant to the embryos, consequently killing them. Embryos from the other collections, however, resulted in callus formation within 5 to 10 weeks after culturing on callus induction medium. The number (and percentage) of immature embryos that formed callus were 110 (55%), 176 (88%), and 132 (66%) obtained from June, July, and August collections, respectively. These results suggest that the best collection date for pine cones in northwest Arkansas for callus induction in 1991 was around the end of July. June and August, however, were also suitable for cone collection if culturing a maximum number of embryos was desired.

Although the percentage of callus induction gave an indication of the capacity of the immature embryos to form callus, the quality of the callus produced, as expressed in its capacity to regenerate plants, was not realized. Therefore, a relationship between the collection date and the capacity to regenerate has not been established. This subject is the objective of further investigation, which will be conducted on 1992 cone collections. Cell suspension established from callus was maintained viable for over 6 months. Initially, the callus suspension appeared white but gradually changed to brown after about 30 days in suspension, even though subculturing at 2-week intervals was carried out. This problem was circumvented by periodic interruption during the growth in liquid cultures and the transfer of callus to solid medium. When the brown callus was placed on agar medium, proliferation of white callus resumed. This new callus proliferation was useful in establishing new cell suspension cultures. Using this method, we achieved a continuous source of callus for studying the differentiation process. Evidence of redifferentiation and somatic embryo formation was observed based upon staining techniques.

CYTOCHEMICAL STAINING OF REDIFFERENTIATING CALLUS

Medium designed to induce differentiation and somatic embryo formation contained a lower level of 2,4-D. This alteration in the medium was sufficient to induce differentiation of non-differentiated callus into various stages of development. These stages were observed with the staining method described by Gupta and Durzan (1987a). This double-staining provides a means for the identification of certain structures based upon their color rendered after staining; for example, red indicates embryonic tissue, and blue indicates suspensor. Some stages of development observed in our study are presented in Fig. 1. Although the colors are useful indicators, in the black and white photos only the shapes of the structures are visible. Differentiation began after the non-differentiated callus (Fig. 1, A) was placed on regeneration medium where it formed an early proembryonic complex, which continued to develop, forming proembryo masses and leading to the formation of proembryos (Fig. 1, B). The proembryo development was followed by cell elongation (Fig. 1, C) and the formation of a dark red-stained proembryo with a light blue-stained suspensor region (Fig. 1, D). This was the last stage of development observed in this study, and more research is needed to induce conversion of the proembryos to mature embryos. The manipulation of the growth regulators will be our tool to achieve this conversion and the subsequent regeneration of plantlets.

CONCLUSION

Our investigation showed that July was the optimum period of the year to harvest cones for the purpose of pine callus induction in northwest Arkansas. Defining this time is critical for investigations related to pine tissue culture and the development of improved methods for plant regeneration. In addition to achieving this prerequisite for further research, we have demonstrated the establishment and maintenance of callus and callus suspension cultures and observed early stages of somatic embryogenesis.
LITERATURE CITED


BACTERIOLOGICAL WATER QUALITY OF
BEAVER RESERVOIR, ARKANSAS

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ABSTRACT

Beaver Reservoir water quality was determined through enumeration of Total coliforms and Fecal coliforms bacterial parameters at selected locations during 1991. Several areas of the reservoir contained high numbers of indicator bacteria, suggesting excessive fecal contamination. Significant numbers of salmonella-like bacteria were also cultured on SS agar, and several strains were serotyped positive for Salmonella antigens.

INTRODUCTION

Beaver Reservoir is a Corps of Engineers impoundment of approximately 12,000 hectares on the White River in northwestern Arkansas. During the past two decades, this area of the state has experienced dramatic growth in both human population and industry. Demands on the reservoir for recreation, as a water supply and for waste disposal have increased proportionally. Therefore, water quality must be a concern for all who depend upon the reservoir for a source of clean, natural water. This paper resulted from a contractual study carried out during April-December, 1991, and the data suggest the reservoir is receiving a significant load of organic waste. This raises the question of how long the reservoir can continue to serve its multiple uses under such stress.

METHODS AND MATERIALS

Samples were collected as surface grab samples in sterile Whirl-pak bags biweekly from April through October, and once during December, 1991. The locations of sampling stations are presented in Table 1. Bacterial analyses included Total coliforms (TC) on mEno and Fecal coliforms (FC) on mFC media (Difco) according to standard methods of membrane filtration (APHA, 1990).

Enumeration of salmonella-like bacteria was on SS medium (Difco) by membrane filtration. One or more typical colonies were isolated from each enumeration plate for further characterization. Serotypes were determined with Salmonella O poly A-I and VI and Salmonella H poly a-z antisera (Difco). Two strains of Salmonella enteritidis (ATCC 13076 and Carolina Biological Supply Co.) were used as positive controls.

RESULTS AND DISCUSSION

The main stem of the reservoir which appeared to be relatively free of contamination (Stations 1, 3, 4, 6; Table 2). Comparison of stations 7 and 8 suggest the Fayetteville wastewater treatment facility approximately doubled the load of fecal contamination carried into the upper riverine section of the reservoir. The highest numbers of bacteria encountered were from station 9 on Town Branch, which flows from the city industrial park. Stations 7-12 could all be considered major tributaries to the reservoir proper, and all contained significantly higher numbers of bacteria than the reservoir main stem.

Table 2. Mean number of coliforms at each station

<table>
<thead>
<tr>
<th>Station</th>
<th>No.</th>
<th>Numbers of coliform bacteria* (cfu/100 ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Total coliforms</td>
</tr>
<tr>
<td>1</td>
<td>14</td>
<td>146/348</td>
</tr>
<tr>
<td>3</td>
<td>16</td>
<td>202/187</td>
</tr>
<tr>
<td>4</td>
<td>17</td>
<td>287/362</td>
</tr>
<tr>
<td>6</td>
<td>17</td>
<td>312/322</td>
</tr>
<tr>
<td>7</td>
<td>12</td>
<td>428/4700</td>
</tr>
<tr>
<td>8</td>
<td>14</td>
<td>972/19749</td>
</tr>
<tr>
<td>9</td>
<td>18</td>
<td>34761/77902</td>
</tr>
<tr>
<td>10</td>
<td>16</td>
<td>7577/8736</td>
</tr>
<tr>
<td>11</td>
<td>15</td>
<td>6068/7731</td>
</tr>
<tr>
<td>12</td>
<td>17</td>
<td>7548/9632</td>
</tr>
</tbody>
</table>

* mean/standard deviation
All stations yielded some Salmonella-like bacteria (Table 3). The reservoir main stem contained the lowest numbers. The tributaries were

Table 3. Mean number of Salmonella-like bacteria at each sampling station.

<table>
<thead>
<tr>
<th>Station No.</th>
<th>No. of Samples</th>
<th>Mean (cfu/100 ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>18</td>
</tr>
<tr>
<td>6</td>
<td>3</td>
<td>15</td>
</tr>
<tr>
<td>7</td>
<td>3</td>
<td>283</td>
</tr>
<tr>
<td>8</td>
<td>3</td>
<td>787</td>
</tr>
<tr>
<td>9</td>
<td>4</td>
<td>1260</td>
</tr>
<tr>
<td>10</td>
<td>3</td>
<td>2360</td>
</tr>
<tr>
<td>11</td>
<td>3</td>
<td>480</td>
</tr>
<tr>
<td>12</td>
<td>3</td>
<td>887</td>
</tr>
</tbody>
</table>

significantly higher, particularly Town Branch and Richland Creek. Further characterization of these isolates indicated them to be Salmonella spp. which may constitute a threat to public health (Table 4).

Table 4. Characterization of Salmonella-like isolates.

<table>
<thead>
<tr>
<th>Character</th>
<th>Isolates positive/Total tested</th>
</tr>
</thead>
<tbody>
<tr>
<td>SS agar</td>
<td>46/46 Typical colonies</td>
</tr>
<tr>
<td>Gram stain</td>
<td>46/46 Gram(-) bacilli</td>
</tr>
<tr>
<td>MacConkey agar</td>
<td>31/46 Nonfermenters</td>
</tr>
<tr>
<td>TSI agar slant</td>
<td>15/46</td>
</tr>
<tr>
<td>Poly O serotypes</td>
<td>15/46</td>
</tr>
<tr>
<td>Motility</td>
<td>12/15</td>
</tr>
<tr>
<td>Poly H serotypes</td>
<td>10/15</td>
</tr>
</tbody>
</table>

A recent review of water quality data from other studies of the reservoir pointed out excessively high fecal coliform numbers in some areas with an extreme of 14,000 cfu/100 ml at the Richland Creek site (Moore, 1991). Therefore, it is concluded that the reservoir has been receiving a large amount of contamination for several years.

Beaver Reservoir is heavily used for primary contact recreation and as a municipal water source. This study indicated the reservoir is receiving a large burden of fecal contamination from multiple sources. Although the protocols established by the Arkansas State Health Department and Department of Pollution Control and Ecology (DPCE, 1985) regarding sampling frequency were not followed, it seemed likely that some tributaries of the reservoir would exceed the standards for safe primary contact recreational use. The major downstream areas of the reservoir remain relatively free of contamination. However, the condition of the tributaries along with the presence of potentially pathogenic salmonellae suggest that some corrective measures are needed to prevent further deterioration of water quality.

ACKNOWLEDGMENTS

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LITERATURE CITED


SCF-MO AND MONTE CARLO CALCULATIONS OF POLY (DIMETHYLSILOXANE)

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ABSTRACT

Self-consistent-field molecular orbital calculations are being used more and more extensively in determining the energies and properties of various confirmations of polymers. We are using the semi-quantum mechanical procedure MNDO (moderate neglect of differential overlap) to obtain various rotational conformational states of poly(dimethylsiloxane) (PDMS). Before calculation of these states, the molecule is geometrically optimized by using the ab initio procedure Gaussian 86 at the 3-21G basis set level. Generations of 14 rotational states by rotating about two bonds simultaneously in increments of 30° were created. A potential energy surface was created from which Monte Carlo generated several polymer characteristics including characteristic ratio and radial distributions.

INTRODUCTION

Advanced computers and programs are allowing for numerous, very tedious calculations to be done on a variety of applications. One of those applications is the self-consistent-field molecular orbital ab initio calculations (SCF-MO) to obtain rotational potential energy surfaces of molecules. Once a rotational potential energy surface is created, a Monte Carlo calculation procedure can predict certain characteristics of polymer chains it grows, using the optimized geometry and energy surface supplied. Some of these characteristics include characteristic ratio and radial distribution. These Monte Carlo simulations can be run at different temperatures to provide another characteristic, temperature coefficient.

The inorganic polymer poly(dimethylsiloxane) (PDMS) is one of several polymers studied in this research over the past year. PDMS was chosen because of it's unique structure with an alternating silicon-oxygen backbone, containing methylated silicons, which puts it in the class of polymers called siloxanes. These silicon polymers are used in such applications as lubricants, gaskets, defoamers, and elastomers (Billmeyer, 1984). PDMS is very important in this class of polymers in that it has applications in gaskets and seals, and has been a subject of controversy lately because of use in prosthetic devices such as breast implants (Billmeyer, 1984; Rochow, 1987).

The configurational properties of poly(dimethylsiloxane) have been studied over the years both experimentally in laboratories, and with calculations. These configurational properties are unique in that PDMS has differing bond angles. The Si-O-Si angle is much greater than that of the O-Si-O angle, giving the accepted preferred conformation of the all-trans form, or cyclic form. These properties were obtained in large part due to calculations based on rotational isometric state theory (Mark and Flory, 1964; Flory et al., 1964; Flory and Chang, 1976; Mark, 1978; Flory, 1969). Due to this cyclic form, the polymer closes upon itself after about 22 bonds (Mark and Flory, 1964; Flory et al., 1964; Flory, 1969).

It is the purpose of this study to continue efforts to upgrade prediction of polymer characteristics using calculations, and in particular, to predict and confirm average poly(dimethylsiloxane) characteristics.

MATERIALS AND METHODS

The segment of poly(dimethylsiloxane) used for this research consisted of a five member backbone starting with oxygen and is depicted in Figure 1. The size of this segment was determined by calculation, computer, and time constraints of this research. This was done to optimize the geometry of the specified segment of PDMS using the Gaussian 86 (Frisch et al., 1988) ab initio program, then calculate the rotational potential energies using the procedure MNDO (ChemDraf II, 1989; Dewar and Thiel, 1977), and finally, use the Monte Carlo method (Binder, 1987) to make polymer predictions based on the created potential energy surface. These calculations were carried out on a VAX Station 3100 and various 286/386 computers.

Figure 1. PDMS segment used in calculations with rotation sites.

The segment of PDMS chosen had to be optimized before other calculations could be carried out. First, an internal coordinate data set was created in the Z-matrix form that included bond lengths, bond angles, and dihedral angles; all of which had the appropriate reference atom included. The initial geometrical parameters (Flory, 1969) are listed in Table I. To make sure the Z-matrix geometry was correct, the program ChemDraf II (1989) was used to visually check the geometry. To optimize, the Gaussian 86 program was used first to optimize first the bond lengths, then the bond angles. The basis set used for optimization was the STO-3G level of approximation, followed by a higher basis set, 3-21G, which is a split-valence basis set. Higher basis sets would have been better, but program restraints would not allow for this due to the size of the silicon atoms. Once optimization was completed, the geometry was again visually checked to make sure the optimized parameters looked reasonable.

Table I. Some initial parameters from Flory (1969).

<table>
<thead>
<tr>
<th>GEOM. PARAM.</th>
<th>INITIAL</th>
<th>STO-3G</th>
<th>3-21G</th>
</tr>
</thead>
<tbody>
<tr>
<td>Si-O</td>
<td>1.67 Å</td>
<td>1.6422 Å</td>
<td>1.6767 Å</td>
</tr>
<tr>
<td>Si-C</td>
<td>1.80 Å</td>
<td>1.8683 Å</td>
<td>1.8952 Å</td>
</tr>
<tr>
<td>O-H</td>
<td>0.90 Å</td>
<td>0.9630 Å</td>
<td>0.9712 Å</td>
</tr>
<tr>
<td>C-H</td>
<td>1.00 Å</td>
<td>1.0607 Å</td>
<td>1.0863 Å</td>
</tr>
<tr>
<td>O-Si-O</td>
<td>109.0°</td>
<td>104.1256°</td>
<td>108.9325°</td>
</tr>
<tr>
<td>Si-O-Si</td>
<td>143.0°</td>
<td>143.2753°</td>
<td>143.075°</td>
</tr>
<tr>
<td>C-Si-O</td>
<td>109.5°</td>
<td>110.8980°</td>
<td>110.5136°</td>
</tr>
<tr>
<td>H-C-Si</td>
<td>109.5°</td>
<td>111.4374°</td>
<td>111.2324°</td>
</tr>
<tr>
<td>H-O-Si</td>
<td>109.5°</td>
<td>108.3012°</td>
<td>126.9710°</td>
</tr>
</tbody>
</table>
The rotational potential energies were created by rotating about two internal backbone bonds seen as $\varphi_1$ and $\varphi_2$ in Figure 1. While $\varphi_1$ was held, $\varphi_2$ was rotated through 360° by 30° increments; then $\varphi_1$ was rotated 30° and the process repeated until $\varphi_1$ had been rotated through 360°. To reflect these rotations, the dihedrals of the atoms one bond away from the rotation bond were changed according to the rotation amount. These rotations were represented by a total of 144 rotation data sets that were to be used in the actual calculations. The energies of these 144 data sets were calculated by the semi-quantum mechanical procedure MNDO (moderate neglect of differential overlap) in the program ChemDrafl II. The reason this calculation procedure was used rather than the Gaussian 86 calculation was because each rotational energy calculation using Gaussian 86 took approximately two to three hours to complete, while the MNDO procedure took two to three minutes. Since there were 144 rotations in each run, the MNDO procedure was very advantageous. These calculations produced a list of 144 rotations with the corresponding energies expressed in Hartree units. These energies were then converted into kilocalories relative to the lowest energy, where the lowest energy was set at 0.0 kilocalories.

The list of relative rotational potential energies was used by Monte Carlo to produce a rotational energy map as depicted by Figure 2. Monte Carlo used this energy map to mathematically create a probability space. The Boltzmann factor is the basis of the mathematics and is given by the following formula:

$$P_i = e^{-\frac{E_i}{kT}}$$

Using the probability space created, each rotation set had its own probability of being chosen in a random number generator. The lower the relative energy, the greater chance the rotation set had to be used in a growing polymer chain. The Monte Carlo program was set to grow a set of 10,000 polymers, that were approximately 100 bonds long (put in two at a time), consisting of only the backbone atoms. Only the backbone atoms were used because the methyl groups were taken in account when the probability space was created. The reason that there were 10,000 simulations of 100 bond long polymer chains was because at these parameters, the characteristics calculated didn’t change appreciably between repeated runs. Another parameter in the Monte Carlo program was the temperature at which the simulations were to be run. Changing of the temperature allowed the calculation of the temperature coefficient by using data from the temperatures 300, 400, and 500 K. Monte Carlo calculated various average statistical properties by calculating over the 10,000 chains. The mean square end-to-end distance was calculated for each chain, from which the characteristic ratio and temperature coefficient were calculated. These characteristics are given by the formulas

$$C_n = \frac{\bar{R}_n^2}{n/2}$$
and

$$d \ln \frac{\bar{R}_n^2}{n/2} = \frac{1}{kT}$$

where $\bar{R}_n$ is the mean square end-to-end distance of the 10,000 chains, $\bar{R}_n$ is the average bond length, and $n$ is the number of bonds in the chain.

Monte Carlo also gave the radial distributions, which are the number of times two atoms are $n$ angstroms apart, and it also gave the angular distribution, the number of times a particular rotation set was used.

**RESULTS AND DISCUSSION**

The minimal basis set of function, STO-3G, was used to obtain the second set of parameters seen in Table I. The parameters most concerned with were the Si-O bond length, the O-Si-O angle, and the Si-O-Si angle. These three when optimized by the STO-3G basis set were an average of 1.81% off the experimental parameters listed in Table I. To achieve better optimized results, the split level basis set function, 3-21G, was used. Using the 3-21G basis set achieved an average deviation of 0.44% for the three parameters previously mentioned, which was a four fold decrease.

As noticed in Table I, the H-O-Si bond angle changes considerably when optimized by the 3-21G basis set. This can be explained by the fact that 109.5° is arbitrarily used as an initial value, as were the C-Si-O and the H-C-Si angles, in accordance to expected sp3 bonding. The angle of 126.9° is not unexpected in light of it’s environment in the polymer segment.

The MNDO method of calculation was used in determining the rotational potential energies, and the results can be seen in the three dimensional rotational energy map of Figure 2. The X in the energy map marks the lowest energy (map global minimum) rotation set, 180-210. Some other low rotation sets in order of increasing energy include the following: 180-150, 180-180, 150-240, and 180-240. Conversely, the highest rotation sets, in order of increasing energy, include the following: 30-90, 60-90, 90-90, and 300-240. These rotation sets would seem to suggest that a polymer using these preferred sets would be in the cyclic, convoluted conformation, and would shun the unpreferred, which would put methyl groups close to other methyl groups and/or oxygen atoms.

The Monte Carlo method was used to predict PDMS polymer characteristics that included characteristic ratio and temperature coefficients. Table II lists characteristic ratios with the corresponding temperature of this research and other sources. The characteristic ratios

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Characteristic Ratio</th>
<th>Characteristic Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>300 K</td>
<td>400 K</td>
<td>500 K</td>
</tr>
<tr>
<td>180 150</td>
<td>14155</td>
<td>180 210</td>
</tr>
<tr>
<td>180 210</td>
<td>14014</td>
<td>180 150</td>
</tr>
<tr>
<td>180 180</td>
<td>13931</td>
<td>180 180</td>
</tr>
<tr>
<td>150 240</td>
<td>13299</td>
<td>150 240</td>
</tr>
<tr>
<td>180 240</td>
<td>12355</td>
<td>180 240</td>
</tr>
</tbody>
</table>

---

**Table 2.** Characteristic ratios with corresponding temperatures and temperature coefficients of this work (Monte Carlo) and others. 8(Carroll and Mark, 1984), 9(Flory and Chang, 1976), 10(Darsey, 1990), 11(This work), 12(Mark and Erman, 1988), 13(Mark and Erman, 1988), 14(Darsey, 1990), 15(This work).

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calculated seem in accordance with other values from literature, which vary greatly in some. Using our three characteristic ratios, a temperature coefficient graph was created, Figure 3, from which the PDMS temperature coefficient was calculated and is listed in Table II. The

![Temperature Coefficient Graph](image)

**Figure 3.** Graph of $\ln \langle r^2 \rangle$ vs. Temp. in K to produce temperature coefficient.

The temperature coefficient, $-0.61 \times 10^{-3}$ K$^{-1}$, as seen with others in Table II, has approximately the same magnitude, but is a negative value rather than a positive one, which predicts that the polymer actually tightens rather than relaxing with increased temperature. Some insight into our value can be given if the radial distribution (Figure 4) and the angular distribution (Table III) are studied. As the energy was increased from 300K to 500K, the characteristic ratio, a measure of the "tightness" of a polymer, decreases, which means the polymer became more convoluted. As seen in Table III, as energy was increased the polymer tended to not spend as much time in the normal conformation denoted by the angles listed, but occupied higher energy rotational sets which convoluted the polymer to a more globular shape. The radial distribution, Figure 4, shows that at 300K, the number of atoms apart by 22Å to 55Å is more than at 400K or 500K, and at 0Å to 22Å is less than the other temperatures. Looking at 500K, just the opposite is true, and 400K falls in between. This graph supports the findings that as the temperature increases, thus the energy, the polymer conforms to a state where it is more compact.

![Radial Distribution Graph](image)

**Figure 4.** Graph of radial distributions produced by Monte Carlo at three temperatures from 0 to 55Å further points cut off due to graphing purposes.

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### Table 3. Five most used angular distributions for each temperature from Monte Carlo calculations.

<table>
<thead>
<tr>
<th>CHAR. RATIO</th>
<th>TEMP K</th>
<th>TEMP. COEFF. x10$^{-3}$/K</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.62-5.90 (a)</td>
<td>298.0</td>
<td>+0.59 (e)</td>
</tr>
<tr>
<td>6.43 (b)</td>
<td>383.0</td>
<td>+0.52 (f)</td>
</tr>
<tr>
<td>4.17 (c)</td>
<td>423.0</td>
<td>+0.511 (g)</td>
</tr>
<tr>
<td>4.1025 (d)</td>
<td>300.0</td>
<td>-0.61 (h)</td>
</tr>
<tr>
<td>3.7783 (d)</td>
<td>400.0</td>
<td></td>
</tr>
<tr>
<td>3.6466 (d)</td>
<td>500.0</td>
<td></td>
</tr>
</tbody>
</table>

Several factors could have influenced the data obtained in this research. First, and most important, since MNDO had to be used in the calculation of the rotational potential energies, they were not as accurate as with using a Gaussian split valence basis set. We believe this has the greatest affect on the results. In optimizing, we were also restrained in that a higher basis set level could not be used due to program ability. A higher basis set here would also have been an asset. Another factor is that our segment of PDMS that was utilized started with oxygen rather than silicon, which had been used in earlier studies. In the data referenced in Table II, for the experiments, PDMS was dissolved in solvents that affect characteristics that can not be taken into account when using theoretical calculations. All of these factors in differing importance, probably represent the differences seen in our data.

This research has been invaluable in that future projects can be refined using what was learned here, and hopefully theoretical calculations of this type can be done with increasing certainty. This research is also valuable in that it will be used in a neural network project that is ongoing.

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### SUMMARY

A segment of poly(dimethylsiloxane) was geometrically optimized using a split valence level, 3-21G, Gaussian program. A set of 144 rotational potential energies was created using the MNDO method to calculate. The optimized geometry and the rotational potential energies were used in a Monte Carlo method to create a probability space that simulated 10,000 polymer chains at three different temperatures. The characteristics determined suggest that PDMS is in a cyclic form, preferring to use the angles 180° and 210°, and convolutes to a greater extent when energy is increased, thus giving a negative temperature coefficient.

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### ACKNOWLEDGMENT

The authors wish to thank Dr. Al Karlin of University of Arkansas at Little Rock for the use of the computer lab and the mounds of computer assistance needed throughout this research. We also wish to thank Mrs. Robin Long of UALR for her computer assistance. Acknowledgment of partial financial support is given to the donors of the Petroleum Research Fund, administered by the American Chemical Society and also of partial financial support by the Faculty Research Grant of the University of Arkansas at Little Rock.
LITERATURE CITED


COMPARISON OF TWO MODELS FOR BREAKDOWN WAVES

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ABSTRACT

In this paper, the two theories concerning the propagation of breakdown waves are compared. The two theories are as follows:

1. The photoionization theory, in which the driving force of the propagation is the electromagnetic radiation from the hot gas generated at the electrode with the greatest potential gradient.
2. The electron fluid dynamical theory, in which the driving force of the propagation is the partial pressure of the high temperature electron gas generated in the neighborhood of the pulsed electrode. Successes in explaining the experimental data will be compared.

INTRODUCTION

Lightning, one of nature's most awesome phenomena, has intrigued mankind for centuries. The scientific community has devoted years of research in an attempt to duplicate the lightning stroke in the laboratory and study its nature. As early as the 1700's, physicists were observing discharges similar to lightning. Hawksbee (1706/1707) saw flashes of light coming from the evacuated tube over the mercury column of a barometer when it was vibrated. Thompson (1893) began using a 15 meter long discharge tube to study ionizing waves. He was able to measure the speed of waves traveling at one half the speed of light. Beams (1930) using a Kerr cell, observed that the fast light pulse began at the high potential electrode. Technology improved after the second World War, and many new studies were performed. The 1960's mark the introduction of sound theoretical advances in the study of breakdown waves. This paper will introduce and compare the two theories (the photoionization theory and the fluid-dynamical theory) regarding the driving force of the propagation of the breakdown waves.

The photoionization theory assumes that the ionizing radiation from the hot gas formed at the electrode with the greatest potential gradient is the primary driving mechanism for the front that moves out from the hot gas. The fluid-dynamical model treats the waves as a three fluid model consisting of electrons, positive ions, and neutral particles. The primary driving mechanism in this treatment is the partial pressure of the high-temperature electron gas behind the shock front. From the beginning of the 1940's until the mid 1970's the photoionization theory received much attention in both the experimental and theoretical fields. Although this theory has been investigated fully, mathematical formulations with solutions in good agreement with the experimental results have not been achieved. The mathematical formulation of the fluid-dynamical model has shown great success in explaining the experimental data collected up to now. Hence, most of the recent works have centered around the fluid-dynamical model.

THEORIES

Snoddy et al. (1937) varied different experimental parameters to study their effects on wave speeds. They found that their computed speeds were approximately 40% greater than the average speed measured over a given distance. Their work also showed an apparent increase in the speed as the negative input voltage wave traveled down the tube, while the positive input voltage wave decreased in speed. They said the speed was greatly increased by the ionization in the gas ahead of the front. Although they could not determine the exact mechanism of discharge, they speculated that it depended on the transfer of potential down the tube by ionization processes of the Townsend type.

The photoionization model consists of the following several points. The breakdown initiates at the electrode with the largest potential gradient. There, a localized region of hot ionized gas is formed. Ionizing radiation from this hot gas is thought to be the primary driving mechanism for the ionization front that moves out from the hot gas. Photons from excited atoms propagate through the neutral gas ionizing and exciting atoms in front of the wave. In turn, these newly excited atoms emit photons which carry on the process. The ionization front consists of a thin photo-absorbing region between the ionized gas behind the front and the neutral gas ahead of the front. The velocity of the front is determined by the intensity of the ionizing radiation. A single-fluid model is used since there is assumed to be no electrical current. The final form of the set of equations derived by Nelson (1964) using the photoionization theory and the analysis of his derived equations are being discussed fully in his paper.

Paxton and Fowler (1962) used the electron fluid-dynamical approach and obtained good agreement with experimental data from several different experiments. Shelton and Fowler (1968) began working with the fluid model using only one-dimensional calculations. They proposed that the one-dimensional model would be valid due to the cylindrical geometry and symmetry. In other words, if the direction of the propagation of the wave is considered to be along the x-axis, then the structure of the wave in the y and z directions remains constant and calculations need only be applied to the direction of propagation. When Shelton and Fowler (1968) applied their equations to the data of Snoddy et al. (1937), they found that the expected value for the acceleration was 29% instead of the 40% previously reported. They speculated that most of the acceleration of waves could be attributed to the increase in the electric field during the propagation down the tube.

Haberstich (1964) studied waves produced by impulse potentials in an un-ionized gas. He derived a one-dimensional theory for the propagation of the front. Haberstich (1964) assumed that the propagation required only one electron ahead of the front. However, his results are questionable on several counts. He never measured electron temperature. Velocities of the waves were determined by observing only a single event. Also the purity of the gas samples used was uncertain due to the type of pump used to evacuate the system.

In the electron fluid-dynamical model, a small quantity of gas near the electrode with highest potential gradient is ionized and the electrons that are produced are given kinetic energy by the electric field. This high-temperature electron gas rapidly expands, producing a shock wave of electrons which partially ionizes the neutral molecules in the ambient gas. The shock waves are of steady profile, which means if an observer were to view the wave in a reference frame traveling with the wave, there would be no time variation of the structure of the wave.
Shelton and Fowler (1968) proposed one of the most satisfying theories to date. They used a three fluid hydrodynamical model to analyze the case of a one-dimensional wave traveling in the direction that an electron would be accelerated by the applied electric field. In this work, Shelton and Fowler (1968) also introduced the concept of the proforce and antiforce waves. Proforce waves are waves for which the external electric field accelerates the electrons in the direction of wave propagation. The antiforce waves are waves where the electric field force acting on the electrons is in the opposite direction of the wave propagation.

By introducing the dimensionless variables \( \theta, v, \psi, n, \) and \( \xi \) as electron temperature \( T_e \), electron concentration \( n \), electron velocity \( v \), electric field \( E \), and position in the wave profile respectively, the set of equations, the equation of conservation of mass, the equation of conservation of momentum, and the equation of conservation of energy, including the Poisson’s equation respectively become

\[
\frac{\partial \psi}{\partial t} = \kappa \psi, \quad (1)
\]

\[
\frac{\partial \theta}{\partial t} = \frac{-\psi}{\kappa} \left( \frac{\partial \psi}{\partial t} \right) - \frac{\psi}{\kappa} \left( \frac{\partial \psi}{\partial x} \right), \quad (2)
\]

\[
\frac{\partial n}{\partial t} + \frac{\partial (n \psi)}{\partial x} = \beta n, \quad (3)
\]

\[
\frac{\partial \psi}{\partial t} = \kappa \psi, \quad (4)
\]

In the above equations \( \mu \) and \( \kappa \) are the ionization rate, and the elastic collision frequency respectively. \( \kappa = \frac{m \nu}{n} \) where \( \phi \) is the ionization potential of the gas.

Nelson (1964) criticized the Paxton and Fowler’s (1962) fluid-dynamical model. He said that they failed to prove the validity of their zero-current assumption in the wave, because according to his calculation although they had no current flow in the wave frame, they still had current flow in the lab frame. However, if one begins with Poisson’s equation

\[
\frac{\partial E}{\partial x} = -\frac{n}{\kappa} (N_e - n), \quad (5)
\]

and the equations for the production of ions and electrons

\[
\frac{\partial N_e}{\partial t} + \frac{\partial (N_e \psi)}{\partial x} = \beta n, \quad (6)
\]

\[
\frac{\partial n}{\partial t} + \frac{\partial (n \psi)}{\partial x} = \beta n, \quad (7)
\]

the above mentioned statement by Nelson (1964) can be proven invalid. In the above equations \( N_e, V, n, \) and \( \beta \) are ion density, wave velocity, and ionization frequency respectively. By subtracting equation (7) from equation (6), then multiplying both sides of the resulting equation by electron charge \( e \), one obtains the equation

\[
\frac{\partial}{\partial x} \left[ e(N_e - n) \right] + \frac{\partial}{\partial t} \left[ e(N_eV - nv) \right] = 0. \quad (8)
\]

Then, by applying Poisson’s equation, this equation becomes

\[
\frac{\partial}{\partial x} \left[ e(N_e - n) \right] + \frac{\partial}{\partial t} \left[ e(N_eV - nv) \right] = 0. \quad (9)
\]

Integration of this equation gives the following equation

\[
\varepsilon_0 \frac{\partial E}{\partial t} + e(N_eV - nv) = i(0), \quad (10)
\]

where \( i(0) \) is the current ahead of the wave. This equation shows that the total current, convection plus displacement, is independent of position. The electric field ahead of the wave \( E_0 \) had been specified as a constant and the wave is said to propagate into neutral, un-ionized gas, so the right-hand side of the above equation is zero, thus satisfying the zero current condition

\[
N_eV - nv = 0. \quad (11)
\]

This condition holds true for any one-dimensional frame of reference. This disproves the cornerstone in Nelson’s criticism of the electron fluid-dynamical model proposed by Paxton and Fowler (1962).

Using a revision of the breakdown apparatus used by Haberstich (1964), Blais and Fowler (1973) investigated Shelton’s one-dimensional fluid dynamical theory. They confirmed the relationship between wave speed and applied electric field as proposed by Shelton, but found the pressure dependence to be more complicated than previously believed. Blais and Fowler (1973) also established an exponential decrement rule for wave speed as a function of distance down the tube.

Finally Fowler et al. (1984) published a paper dealing with the exact numerical solutions of the set of equations pertaining to the electric breakdown waves. Their studies centered around the approximations which the equation set used by previous physicists was derived and solved. They investigated the addition of new terms to the equation of conservation of energy to try to improve agreement with experimental results. They studied the newly added terms effects on the final outcome of the integration of the set of equations in the shock region. Their most important discovery was the significant relevance of the heat conduction term \(- \frac{2\nu \psi}{\kappa} \frac{\partial}{\partial x} \left[ e(N_eV - nv) \right] \) and the acceptance of the temperature derivative discontinuity at the shock front. Two other terms were found to be relevant for the integration of equations on meeting the boundary conditions at the end of the shock region. These two terms are due to the energy loss by the electrons to the heavy particles in elastic collisions and have to be added to the right hand side of the energy equation

\[
\left. \frac{\partial}{\partial x} \left[ e(N_eV - nv) \right] \right| + \frac{\partial}{\partial t} \left[ e(N_eV - nv) \right] \quad \text{and} \quad \frac{\partial}{\partial x} \left[ e(N_eV - nv) \right] \quad \text{and} \quad \frac{\partial}{\partial t} \left[ e(N_eV - nv) \right] \quad \text{with} \quad m \text{ and } M \text{ are the electron and heavy particle mass’s respectively. The boundary conditions at the end of the shock region are: 1) the electrons have to come to rest relative to the ions and neutral particles, and 2) the electric field had to reduce to zero.}

CONCLUSION

Hemmati and Fowler (1985) were able to apply their modified equations to different classes of waves and found that the solutions were in good agreement with the experimental results obtained by Blais and Fowler (1973). This helped show the fluid model’s application to be quite successful in theoretical explanation of the breakdown waves. In recent years, the fluid model has found more acceptance in the scientific community as opposed to the photoionization model which fails to receive much consideration due to it’s inability to explain a wide range of experimental results.

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Comparison of Two Models for Breakdown Waves

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MEASUREMENT OF THE COEFFICIENT OF THERMAL EXPANSION OF SUPERCONDUCTING THIN FILMS USING POWDER X-RAY DIFFRACTION

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ABSTRACT

The High Density Electronics Center (HiDEC) at the University of Arkansas, Fayetteville is developing the technology for High Temperature Superconductor Multi-Chip Modules (HTSC-MCM's). As part of this work, we are looking at the mechanical properties of HTSC materials. An important mechanical property which influences the mechanical integrity of the hybrid MCM is the coefficient of thermal expansion (CTE) of the HTSC films. As a first step in developing a procedure for the determination of the CTE of HTSC materials, the lattice parameters and the CTE of an α-alumina substrate have been determined by powder x-ray diffraction technique. An extension of this technique applicable to HTSC materials is presented.

INTRODUCTION

The goal of the research presented here is to determine the lattice parameters and the CTE of high temperature perovskite superconductors. These materials are being developed by HiDEC for use as signal propagation layers and interconnects in high temperature superconducting MCM's.

Multi-chip modules represent the next stage in the continual evolution of higher-density, higher-speed electronic packaging technologies. With the clock rates of new generation computers increasing, the chip-to-chip interconnection paths become the limiting factor in system performance. In an MCM, discrete IC packages are eliminated by placing the bare IC's as close as possible on a high density interconnect substrate. One limitation of conventional MCM's is that as the size of the MCM increases, at a constant chip placement density, the average interconnect length increases. If the number of chip rows is increased from 1 to 20 on a square MCM, the average interconnect length will increase by about 35% from 3.1 to 4.2 chip pitches. As a result, wider and thicker material traces are required to avoid excessive resistance. To accommodate these larger cross-section interconnects, conventional MCM's must be made with multiple signal layers, with an accompanying increase in complexity and resultant lower product yields. High temperature superconductor MCM's do not need large cross-section interconnects. Signal propagation delays are also reduced. For 10 GHz operation, a 30 cm copper interconnect line would need to be approximately 35 microns wide compared to less than 2 microns wide for a superconducting interconnect. For superconducting MCM's, two signal layers should always be sufficient. Figure 1 shows a cross-sectional schematic of a superconducting MCM.

A number of key issues need to be addressed before high temperature superconducting MCM's can be successfully fabricated. Superconducting MCM's will require the integration of high temperature superconductors with several materials (insulators, semiconductors, and metals) (Markstein, 1991). Hence, understanding interfacial effects are of crucial importance. The constraints imposed by mismatch of lattice constants between the superconducting material and the substrate need to be known before the mechanical stability of such a multilayered structure can be determined accurately. Also, the difference in the coefficient of thermal expansion between the superconducting material and the substrate can cause cracking during thermal cycling. Since the mechanical properties, including the coefficient of thermal expansion, of many of the high temperature superconducting materials are not well known, it is important that the mechanical properties be characterized. We have begun work to measure the CTE of HTSC thin films using a powder x-ray diffraction technique. We have initially used α-alumina samples, for which the CTE is known, in order to verify the technique.

THEORY AND CALCULATIONS

The phenomenon of x-ray diffraction by crystals results from a scattering process in which the x-rays are scattered by the electrons of the atom without change in wavelength. A diffracted beam is produced by such scattering when certain geometric conditions are satisfied (expressed as the Bragg law or the Laue equations) (Klug and Alexander, 1954). Figure 2 shows a schematic of x-ray diffraction on a crystalline sample.
The resulting diffraction pattern of a crystal, comprising both the positions and the intensities of the diffraction effects, is a fundamental physical property of the substance. Analysis of the positions of the diffraction peaks leads to the determination of the size, shape, and orientation of the unit cell. The Bragg equation for a crystal is commonly expressed as

$$n \lambda = 2d \sin(\theta)$$  \hspace{1cm} (1)

For a crystal of a given inter-planar spacing d, and for a given wavelength \(\lambda\), the various order \(n\) of reflection occur only at the precise values of angle \(\theta\) which satisfy the Bragg equation, and these angles correspond to a particular hkl plane (Miller indices) of the crystal being studied. At other angles there is no reflected beam because of interference.

There are a number of techniques that can be applied for the precise calculation of the unit-cell dimensions (lattice parameters) from the positions of the different hkl peaks of a powder diffraction pattern. The accuracy of each technique depends on the nature of the hkl peak and the angular positions of the peaks used. For example, the Straumanis technique can be used to determine \(a_0\) values accurately if hkl peaks near \(\theta = 90^\circ\) are used and \(c_0\) values accurately if 001 peaks near \(\theta = 90^\circ\) are used for their calculation (Peiser and Rooksy, 1960). A good technique to use for the case where there are a number of diffraction peaks in the angular range from \(\theta = 60^\circ\) to \(90^\circ\) is the Cohen's least squares method (Peiser and Rooksy, 1960). This is the technique we are using to determine lattice parameters.

The quadratic form of the Bragg equation for a hexagonal crystal can be written as

$$\frac{\lambda^2}{3a_0^2}(h^2 + hk + k^2) + \frac{\lambda^2}{4c_0^2}l^2 = \sin^2\theta$$  \hspace{1cm} (2)

To account for the combined action of the systematic errors, an error term \(D \sin2\theta\) is added to equation (2) to get

$$\frac{\lambda^2}{3a_0^2}(h^2 + hk + k^2) + \frac{\lambda^2}{4c_0^2}l^2 + D \sin^2\theta = \sin^2\theta$$  \hspace{1cm} (3)

The meaning of equation (3) is that the observed \(\sin \theta\) angle value for any line above \(\theta = 90^\circ\) will be in error by an amount equal to \(D \sin2\theta\) as a result of the combined action of the systematic errors (for any line above \(\theta = 90^\circ\) the combined action of the systematic errors would amount to an error term of \(D \sin2\theta/\sin(\theta) + 1/\sin(\theta)\)).

As a result of the random reflection errors, however, equation (3) will not hold exactly for any particular reflection, but will vary by a small amount \(\delta\). The procedure for evaluating the lattice parameters by the least squares technique consists of minimizing the effect of the random observational errors given by

$$\Sigma \delta^2 = \left[ \frac{\lambda^2}{3a_0^2}(h^2 + hk + k^2) + \frac{\lambda^2}{4c_0^2}l^2 + D \sin^2\theta - \sin^2\theta \right]^2$$  \hspace{1cm} (4)

Substituting

$$a_r = \frac{\lambda^2}{3a_0^2}, \quad b_r = \frac{\lambda^2}{4c_0^2}, \quad D = 0.0002°$$  \hspace{1cm} (5)

and

$$\delta_r = (h^2 + hk + k^2), \quad \beta_r = \frac{1}{2}, \quad \gamma_r = \frac{1}{2}, \quad \delta_i = \sin^2\theta \left[ \frac{1}{\sin \theta^2} + \frac{1}{\sin \theta^2} \right]$$  \hspace{1cm} (6)

equation (4) reduces to

$$\Sigma \delta_r^2 = \Sigma \left[ a_r \delta_r + b_r \beta_r + c_r \gamma_r - \sin^2\theta \right]^2$$  \hspace{1cm} (7)

For minimum random error, the first derivatives of \(\Sigma \delta_r^2\) with respect to the variables \(a_r, b_r, D, c_r\) should be zero. The advantage of the least squares technique is that it can be used on any diffraction pattern as long as there are sufficient number of lines to get a good average value of the lattice parameters. The disadvantage is that equal importance is given to reflections at all angles. This method will give accurate results when the lines near \(\theta = 90^\circ\) are used to calculate the lattice parameters. The derivatives of equation (7) give the three normal equations (8):

$$A \Sigma \delta_r^2 = B \Sigma \delta_r^2 + C \Sigma \delta_i^2 = \Sigma \delta_r^2 \sin^2\theta$$  \hspace{1cm} (8a)

$$A \Sigma \delta_r^2 = B \Sigma \delta_r^2 + C \Sigma \delta_i^2 = \Sigma \delta_r^2 \sin^2\theta$$  \hspace{1cm} (8b)

$$A \Sigma \delta_r^2 = B \Sigma \delta_r^2 + C \Sigma \delta_i^2 = \Sigma \delta_r^2 \sin^2\theta$$  \hspace{1cm} (8c)

These can be solved for \(a_r, b_r, D, c_r\) and \(c_r\). The lattice parameters \(a_0\) and \(c_0\) can then be calculated from equations (5), where the wavelength \(\lambda\) of the incident radiation is known.

In the case of an orthorhombic crystal, the normal equations which would give a minimum value of the random errors are given by equations (9):

$$\Sigma \delta_r^2 (A \delta_r + B \beta_r + C \gamma_r + D_1 - \sin^2\theta) = 0$$  \hspace{1cm} (9a)

$$\Sigma \delta_r^2 (A \delta_r + B \beta_r + C \gamma_r + D_2 - \sin^2\theta) = 0$$  \hspace{1cm} (9b)

$$\Sigma \delta_r^2 (A \delta_r + B \beta_r + C \gamma_r + D_3 - \sin^2\theta) = 0$$  \hspace{1cm} (9c)

Here,

$$A = \frac{\lambda^2}{4a_0^2}, \quad B = \frac{\lambda^2}{4b_0^2}, \quad C = \frac{\lambda^2}{4c_0^2}$$  \hspace{1cm} (10)

and

$$\delta_r = (h^2 + hk + k^2), \quad \beta_r = \frac{1}{2}, \quad \gamma_r = \frac{1}{2}, \quad \delta_i = \sin^2\theta \left[ \frac{1}{\sin \theta^2} + \frac{1}{\sin \theta^2} \right]$$  \hspace{1cm} (11)

In the present work, equations (8) were used to calculate \(A, B, c_r\) and \(D\) and values (5) was used to calculate the lattice parameters \(a_r \) and \(c_r\).

EXPERIMENTAL SETUP

Initial lattice parameter and CTE measurements indicated that the resolution and repeatability that could be obtained using a strip chart to record the diffraction peaks was poor. A small percentage difference (3.1% difference in \(a_r\) and 2.5% difference in \(c_0\)) in lattice parameter measurements during different runs with the same conditions caused an error of more than an order of magnitude in the CTE values. Therefore, a computer data acquisition system was added to the diffractometer. An incremental optical encoder with a disc resolution of 5000 pulses per revolution was attached to a micrometer shaft of the goniometer. The micrometer shaft is attached to the goniometer by a tightly fitted worm gear and makes a complete revolution per degree turn of the goniometer shaft. We therefore obtain an encoder pulse every 0.72 arc-second turn of the goniometer shaft. An IBM PC compatible computer data acquisition board with a clock counter and 8-channel 16 bit analog to digital converter is used for the data acquisition. The clock counter of the board is used to count pulses from the encoder. The voltage output from the detector of the diffractometer, which corresponds to the amplitude of the reflected x-rays (the y-axis in a strip chart recording) is read by the A/D converter after being filtered and amplified. A BASIC program was written to control the data acquisition board and to process the data.

Two 1 inch square \(\alpha\)-alumina substrate samples were cemented together with a strip heater in between and used as the sample for diffraction analysis. A type K thermocouple was cemented to the back surface of the assembly, and the temperature was measured using a digital thermocouple display. Temperature of the sample was controlled by varying the current to the strip heater.

RESULTS AND DISCUSSION

The diffraction pattern of the alumina sample was taken at two different temperatures: 27°C and 108°C. The goniometer 20 rate was set at 1°/min and the specimen subjected to copper K-\(\alpha\) radiation. Ten diffraction peaks between the angles 26 = 70 to 120° were recorded. The computer data acquisition system enabled the angular position at the peaks to be recorded with a resolution of 0.0002°. Figure 3 shows the [1 2 10] and the [0 0 12] peaks at room temperature. Table 1 shows the angular positions of the hkl peaks at the two different temperatures. The
Biju Chandran, R. Calvin Goforth, and S. Nasrazadan

Table 1. Observed and corrected 20 positions at different hkl planes.

<table>
<thead>
<tr>
<th>hkl</th>
<th>20°c</th>
<th>20°m</th>
<th>20°m'</th>
<th>20°m''</th>
<th>20°d</th>
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<tbody>
<tr>
<td>0 1 0</td>
<td>76.7423</td>
<td>76.7918</td>
<td>76.7369</td>
<td>76.7423</td>
<td>76.7918</td>
</tr>
<tr>
<td>1 1 2</td>
<td>86.4062</td>
<td>86.4521</td>
<td>86.3429</td>
<td>86.3483</td>
<td>86.3978</td>
</tr>
<tr>
<td>2 1 0</td>
<td>88.8811</td>
<td>88.9306</td>
<td>88.8359</td>
<td>88.8404</td>
<td>88.8999</td>
</tr>
<tr>
<td>0 0 2</td>
<td>90.6704</td>
<td>90.7235</td>
<td>90.5961</td>
<td>90.6015</td>
<td>90.6509</td>
</tr>
<tr>
<td>2 2 6</td>
<td>95.1822</td>
<td>95.2317</td>
<td>95.1741</td>
<td>95.1795</td>
<td>95.2290</td>
</tr>
<tr>
<td>1 2 10</td>
<td>101.171</td>
<td>101.1665</td>
<td>101.0388</td>
<td>101.0442</td>
<td>101.0937</td>
</tr>
<tr>
<td>3 1 8</td>
<td>111.1274</td>
<td>111.1769</td>
<td>110.975</td>
<td>110.9804</td>
<td>111.0299</td>
</tr>
<tr>
<td>3 2 4</td>
<td>116.2100</td>
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<td>116.1832</td>
<td>116.1886</td>
<td>116.2381</td>
</tr>
<tr>
<td>1 1 4</td>
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<td>118.0433</td>
<td>117.9896</td>
<td>117.9950</td>
<td>118.0445</td>
</tr>
</tbody>
</table>

The goniometer does not return precisely to the same starting angle at each run. To account for any starting angle offset between the two runs, the [1 0 0] peak (at 28°-76°) was recorded at the same temperature during both runs. During the high temperature run, the [1 0 0] peak was recorded at 24°C, and the strip heater was turned on to heat the sample uniformly to 108°C before proceeding to the next hkl peak at approximately 80°C. The difference between the angular positions of the [1 0 0] peaks at the two different temperatures was used as a starting angle offset to correct the angular positions obtained during the high temperature run (76.7423°-76.7369° = .0054°). This technique is applicable because all the other errors associated with the x-ray diffraction method, namely absorption and eccentricity errors, remained the same for the two different runs since the sample was not removed from the sample holder between the runs. Column 2 shows the 20 positions recorded at T=24°C, and Column 4 shows those recorded at T=108°C without the offset correction. Column 5 shows the 20 values at 108°C corrected for a starting offset of 0.0054°. Here the starting angle offset for the data at room temperature was neglected.

The lattice parameters a₀ and c₀ were calculated from ASTM published data (Smith and Berry, 1960) using Cohen's least square technique (a₀ = 4.7295 Å and c₀ = 13.0838 Å). These lattice parameter values were used to calculate the correct position of the [1 0 0] peak. This was found to be 76.7918°. The difference (76.7918°-76.7423°) of 0.0495° was used as an offset to correct the room temperature 20 readings. The 20 readings at T=108°C was corrected with the new starting offset value (76.7918°-76.7369° = 0.0549°) calculated from the corrected room temperature readings. The corrected room temperature 20 readings and the corresponding 20 values at 108°C are shown in Columns 3 and 6, respectively.

The lattice parameters were calculated for the uncorrected 24°C 20 readings (Column 2) and the 20 readings at 108°C (Column 5) using the 9 diffraction peaks above 80°. The [1 0 0] peak at 24°C was not used so that the same degree of accuracy could be maintained for the lattice parameters calculated at the two different temperatures.

The normal equations calculated for the room temperature data in column 2 are:

\[
1391A₀ + 3068B₀ + 200.5646D = 60.3804
\]
\[
3068A₀ + 46656B₀ + 1172.656D = 269.6669
\]
\[
200.5646A₀ + 1172.656B₀ + 46.7089D = 11.8169
\]

The lattice parameters calculated from these equations are a₀ = 4.6998 Å, and c₀ = 13.1736 Å. The lattice parameters calculated for the 108°C data in Column 5 are a₀ = 4.6996 Å, and c₀ = 13.1834 Å. The CTE is then given by

\[
a\text{-axis CTE} = \frac{(4.69992 - 4.69981)}{(79.7918° - 76.7423°)} = 2.0488E-6/°C
\]
\[
c\text{-axis CTE} = \frac{(13.1734 - 13.17359)}{(79.7918° - 76.7423°)} = 8.89915E-5/°C
\]

The average CTE is therefore 5.474E-6°C. The lattice parameters and the CTE were similarly calculated from the room temperature 20 values corrected with the starting offset, and the correspondingly corrected 20 readings at 108°C. The CTE obtained using these data is 5.4669E-6°C, which is almost the same as the CTE calculated using the data without the room temperature data corrected for the starting error. Therefore, a small common offset on the two sets of data does not appear to introduce a significant error in the calculated CTE. The CTE value was compared to the published value of 6.3E-6°C (Shackelford, 1992). The CTE calculated using X-ray diffraction is found to be about 13% lower than the published value. One possible reason for this is that the incident x-ray is not entirely Kα, but a mixture of different copper radiations. This produced multiple peaks (one for every wavelength) at each peak location, as can be seen in Figure 4. It is possible that we recorded different wavelength peaks at some peak positions during the two runs. Also, we do not know how much sample-to-sample CTE variation exists in α-alumina.

**DIRECTION OF FUTURE WORK**

Superconducting thin films are deposited on substrates with their c-axis normal to the substrate surface. Since x-ray diffraction only gives diffraction lines for planes parallel to the surface, it is only possible to
calculate $c_0$ (normal to the film surface), and hence the CTE along the c-axis, for an HTSC film as deposited. We are primarily interested in the CTE along the plane of the film surface ($a$-axis CTE for hexagonal crystal, $a$-axis and $b$-axis CTE's for an orthorhombic crystal) since the thermal stress at the thin film and substrate interface will be due to the CTE mismatch parallel to the film surface. Therefore, we are developing a procedure to determine the lattice parameters from diffraction measurements of a pulverized HTSC thin film slurry. Similar procedures have been successfully applied elsewhere (Mizutani et al., 1976). The thin film along with a small portion of the substrate is finely pulverized. The powder needs to be finely ground in order to reduce absorption errors. The powder is then made into a slurry with methanol and pasted on a quartz sample holder. Some HTSC powder absorbs moisture and this can cause the diffraction pattern to change. In such cases, a mixture of toluene and vaseline can be used instead of methanol (Doverspike et al., 1991). If the lattice parameters of the substrate have been previously determined, then the diffraction lines of the substrate can act as an internal standard (Peiser and Rooksey, 1960). Since the errors associated with both the powders are the same, the error associated with the substrate’s lattice parameters can be determined and the error can be used as a correction factor for the calculated thin film lattice parameters. If the substrate’s lattice parameters are not known accurately, then some high purity silicon powder can act as a standard (Mizutani et al., 1976). The diffraction pattern needs to be taken over a large angular range, since the errors associated with x-ray diffraction decrease as the incident angle approaches 90°. Most of the HTSC materials have strong high angle peaks (Yvon and Francois, 1989), (Ece et al., 1991), (Tonouchi et al., 1987), (Zhou et al., 1988).

At this stage of the work, we have verified the x-ray diffraction technique for the determination of the CTE of an alumina sample. We will now measure the CTE of some slurried thin films with well known properties in order to verify the HTSC sample preparation technique described above. Finally, we will use the methods to measure the CTE’s of a variety of YBCO and thallium - based HTSC thin films.

LITERATURE CITED


USING PHYSICAL, CHEMICAL AND BIOLOGICAL INDICATORS TO ASSESS WATER QUALITY ON THE OUACHITA NATIONAL FOREST UTILIZING BASIN AREA STREAM SURVEY METHODS

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ABSTRACT

The Ouachita National Forest (ONF) has developed a series of Best Management Practices (BMP’S) designed to protect water quality and associated beneficial uses (fisheries, municipal water supplies, etc.). A monitoring program is necessary to document the effectiveness of that protection. The Basin Area Stream Survey (BASS) methodology provides a monitoring link from BMP’S to the aquatic ecosystems. The goal of BASS is to identify the physical, chemical and biological characteristics of a stream in a format that will allow comparisons with other streams, and indicate when a stream is being impacted. Six Index streams within two ecoregions were selected and inventoried in 1990, 1991, and 1992, to serve as baseline data sources. The South Fork of Alum Creek and Bread Creek represent the upper Ouachita Mountain Ecoregion; Caney Creek and Brushy Creek represent the lower Ouachita Mountain Ecoregion, and Jack Creek and Dry Creek represent the Arkansas River Valley Ecoregion.

INTRODUCTION

The National Forest Management Act (PL 94-588) requires the Forest Service to maintain or enhance water quality and soil productivity. The Clean Water Act of 1972 (PL 92-500) further requires the protection of beneficial uses and designates the State as the responsible agency. The Environmental Protection Agency has determined that the development and utilization of BMP’S are the methods to meet state water goals for nonpoint pollution.

In conjunction with the States of Oklahoma and Arkansas, the ONF has developed a series of BMP’S (USDA Forest Service, Ouachita National Forest, 1990). These practices, when properly implemented, should protect water quality and associated beneficial uses. While it is assumed that the BMP’S are fully protecting beneficial uses, a monitoring program is necessary to document the effectiveness of that protection. One of the shortfalls of BMP’S is that they are not directly tied to beneficial uses. BASS provides the monitoring link from BMP’S to the aquatic ecosystem and beneficial uses.

Plankuck (1975), Bisson et al. (1981), Hanken (1984) and Ebert et al. (1989) have developed criteria in the form of stream inventories to describe the physical, chemical and biological characteristics of streams. This study applied a paired-basin technique to use stream inventories in assessing the effects of forest management (Punce et al., 1982).

OBJECTIVE

The objective of BASS is to identify the physical, chemical and biological characteristics of a stream in a format that will allow comparisons with other streams, and may identify trends concerning stream health and impairment of beneficial uses.

METHOD AND MATERIALS

The first criteria was the recognition of ecoregions. The ONF used the Arkansas Department of Pollution Control and Ecology’s ecoregion concept (Bennett, et al., 1987) with modification of the Ouachita Mountain Ecoregion. The Ouachita Mountain Ecoregion was separated into an upper and lower subdivision.

Within each ecoregion or subdivision, two watersheds were selected based on past management activities, comparable size, ownership, and proximity. Watersheds containing little or no timber harvesting activities served as control basins, while watersheds with harvesting activities typical of the ONF represented managed basins. Candidate watersheds were large enough to support a resident fishery, with primarily Forest Service ownership, and proximal to the other watershed in the ecoregion (Table 1).

<table>
<thead>
<tr>
<th>Stream</th>
<th>Kilometers</th>
<th>Ecoregion</th>
<th>Control/Managed</th>
</tr>
</thead>
<tbody>
<tr>
<td>S. Alum Fork</td>
<td>7.7</td>
<td>upper Ouachita Mtn</td>
<td>C</td>
</tr>
<tr>
<td>Bread Creek</td>
<td>5.5</td>
<td>upper Ouachita Mtn</td>
<td>X</td>
</tr>
<tr>
<td>Caney Creek</td>
<td>2.5</td>
<td>lower Ouachita Mtn</td>
<td>C</td>
</tr>
<tr>
<td>Brushy Creek</td>
<td>8.6</td>
<td>lower Ouachita Mtn</td>
<td>X</td>
</tr>
<tr>
<td>Dry Creek</td>
<td>9.1</td>
<td>AR River Valley</td>
<td>C</td>
</tr>
<tr>
<td>Jacks Fork</td>
<td>7.0</td>
<td>AR River Valley</td>
<td>X</td>
</tr>
</tbody>
</table>

PHYSICAL

Physical inventories began at the downstream or lower end of the watershed. Moving upstream, habitat types (or reaches) were consecutively numbered beginning with one. The minimum reach identified was ten meters in length. Individual stream reaches were flagged and labeled with the reach number and habitat type. Habitat types were coded according to McCain et al., (1990). The length and width of each reach were measured to the nearest tenth of a meter. Mean bankfull width was visually estimated to the nearest meter.

A transect of depths was measured to the nearest centimeter. The transect measurements occurred at the waters edges, one quarter, half and three quarters of the width. In addition, the depth at the thalweg was measured to the nearest centimeter. All widths and depths were measured at the midpoint of the reach or habitat type. For example, if a reach was 12 meters long, the width was measured at six meters.
Substrate material was expressed as a percentage of the entire area of the reach. Substrates were classified into bedrock, boulder (>30 cm), cobble (8-30 cm), gravel (8-1 cm), sand (1 cm-0.5 cm) and fines (<1 mm), according to a modified Wentworth scale (Bovee and Cochenour, 1977). Embeddedness was estimated as the average percent of cobble-sized substrate surrounded by fines.

Cover factor for fisheries was estimated as a percent of the habitat area. Categories included undercut banks, large woody debris (d>0.15 m, logs and rootwads), small woody debris (d<0.15 m), terrestrial vegetation overhanging stream (h<0.3 m), white water, boulder (d>30 cm), bedrock ledges, clinging vegetation on substrate and rooted vegetation in the stream substrate (Platts et al., 1987).

Each stream bank angle was measured in degrees with a clinometer. For example, vertical banks were 90 degrees, undercut banks were less than 90 degrees (Platts et al., 1987). Bank stability was estimated for each bank, as a percent of the bank intact and/or non-erodible. Terrestrial vegetation was classified as brush, grass, forested or barren. Canopy closure was recorded as the percent of vegetation closure and measured using a spherical densimeter while facing upstream in the middle of the reach.

BIological

The biological inventory was based on a 10% sample of all stream reaches typed. For example, if 27 main channel pools were identified within a stream then three main channel pools were sampled. Sample areas were stratified along the length of the stream.

For fish collections, the habitat reach was isolated with block nets. Collections were made using the multiple-depletion, maximum likelihood estimation method of Van Deventor and Platts (1985). This involved at least two and preferably three or more electroshocking passes through the sample area. These passes covered the entire reach in an upstream progression with consistent effort on all passes. The downstream block net was surveyed for fish after every pass and captured fish were included with that pass. Each pass comprised a sample and was placed in separate containers. Fish were preserved in 10% formalin and labeled. Game species, endangered, threatened, or sensitive species were measured and weighed in the field and returned to the stream.

Aquatic macroinvertebrates were collected with a five-minute kick-net sample, utilizing the same reaches sampled for fisheries. Reaches were sampled as the collector shuffled or kicked the substrate with the dip net positioned directly downstream. All microhabitats (woody debris, leaf packs, etc.) within the reach were included in the sample. At the completion of the five-minute kick sample, an additional five-minute sample from washed substrate was taken. The dip net was placed downstream and individual cobbles were scrubbed with a soft bristle brush into the dip net. That sample was combined with the kick-net sample. Large organic debris and leaves were washed and removed from the sample. Aquatic macroinvertebrate samples were preserved in 70% ethanol and labeled (Merritt and Cummins, 1984).

ChEmaical

Water chemistry and flow data were collected in the same areas sampled for biological characteristics. Volume flow, dissolved oxygen, turbidity and temperature were measured in the field. Water samples were collected and preserved for analysis. Water analysis included suspended sediment, turbidity, conductivity, pH, bromide, nitrate, boron, silicon, zinc, phosphorous, iron, copper, manganese, magnesium, sodium, cobalt, aluminum, nickel, calcium, titanium, chromium, lead, sulfate, acidity and chloride.

discUsSion

The Basin Area Stream Survey is a method for the systematic and comprehensive collection of data in lotic aquatic ecosystems. Following the analysis of the data, the frequency and characteristics of habitat types in a given stream and ecoregion may be compared and contrasted. Within habitat types, physical characteristics, biological criteria and chemical parameters may also be evaluated.

After determining the variability within and between managed and control stream systems and ecoregions or subdivisions, trends in habitat composition and stream characteristics may be monitored. Additionally, the six streams become index streams for comparison to other streams within their respective ecoregions or subdivisions.

In conjunction with management history and sediment models, predictive models concerning beneficial uses may be developed based on management activities. This will allow resource managers to make more informed decisions regarding management practices and provide a link between Best Management Practices and effects on beneficial uses.

ACKNOWLEDGMENTS

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LIterature cited


MODEL FOR THE CO POISONING OF HYDRODESULFURIZATION CATALYSTS. SYNTHESIS AND STRUCTURE OF \( \text{[Ru(CO)}(\text{PPh}_2\text{SC}_1\text{H}_7)]_2\text{Cl}_2 \) \( \cdot \) 2\text{CH}_2\text{Br}_2. \\

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ABSTRACT

The treatment of \( \text{[Ru[(PPh}_2\text{SC}_1\text{H}_7)]_2\text{Cl}_2} \) with CO at ambient conditions results, after work up, in the isolation of the monocarbonylated species \( \text{[Ru(CO)}(\text{PPh}_2\text{SC}_1\text{H}_7)]_2\text{Cl}_2 \). Crystals of I (C$_5$H$_5$Br$_2$Cl$_2$OP$_2$RuS$_2$: F.W. = 1284.6) are triclinic; \( \alpha = 11.387(3), \beta = 13.010(4) \), \( c = 11.409(3) \), \( \alpha = 93.32(2)^\circ, \beta = 106.51(2)^\circ, \gamma = 91.29(2)^\circ; Z = 2; V = 2495(1) \text{~mm}^3 \). The geometry about the \( \text{Ru(II)}\) center is pseudo-octahedral, with the phosphine ligands in the \text{trans} configuration. The Ru-S bond distance is 2.425(3) \text{~mm}.

INTRODUCTION

The hydodesulfurization (HDS) of fossil fuels is the industrial process for the removal of sulfur from fossil fuel feedstocks (eq. 1).

\[ \text{R-S-R + 2H}_2 \overset{\text{CATALYST}}{\longrightarrow} 2\text{R-H} + \text{H}_2\text{S} \] (1)

The resulting hydrotreated product is then suited for the sulfur sensitive cracking and reforming catalysts downstream. Hydrotreated fuels are also desirable because they generate fewer acid rain precursors upon combustion.

The molecular basis of the HDS process involves the activation of the crude feedstock in hydrogenolysis by metal catalysts. Molybdenum-based catalysts are widely used, although recent work has shown that ruthenium-based systems are even more active (Pecoraro and Chianelli, 1981; Chianelli et al., 1984; Harris and Chianelli, 1984). The organosulfur compounds targeted by HDS consists of thiols, disulfides and thiophenes, especially benzo- and dibenzothiophenes (DBT). In order to elucidate the nature of the substrate-catalyst interactions we sought to prepare ruthenium complexes of DBT-derivatives. In 1984 we reported the first such complex in the form of \( \text{[Ru[(PPh}_2\text{SC}_1\text{H}_7)]_2\text{Cl}_2} \) where \( \text{PPh}_2\text{SC}_1\text{H}_7 \) is 4-diphenylphosphinoDBT, a P-S chelating ligand (Lombardo et al., 1984). As this was the first S-bound DBT complex, we are interested in probing its reactivity in order to evaluate the lability of the Ru-S bonds. We selected CO as the competing ligand since it was known that CO poisons HDS catalysts (Lombardo et al., 1980).

MATERIALS AND METHODS

The compound \( \text{[Ru(CO)}(\text{PPh}_2\text{SC}_1\text{H}_7)]_2\text{Cl}_2 \), I, was prepared by purging a dichloromethane solution of \( \text{[Ru(CO)}(\text{PPh}_2\text{SC}_1\text{H}_7)]_2\text{Cl}_2 \) with CO gas. The resulting solution was concentrated and chromatographed on silica gel, eluting with dichloromethane. The yellow band was evaporated to give yellow microcrystals. Anal. calcd. for C$_{63}$H$_{68}$Cl$_2$OP$_2$RuS$_2$: C, 62.82; H, 3.63; Cl, 7.59. Found: C, 63.34; H, 3.79; Cl, 7.66. IR (CH$_2$Cl$_2$ soln); \( \nu_{\text{carb}} = 1988 \text{~cm}^{-1} \). 31P NMR (CDCl$_3$); 50.63, 41.56, 20.64, 11.62 ppm; S$_A = 45.38, S_B = 16.84, J = 366 \text{~Hz} \). The elemental analysis was performed at the School of Chemical Sciences, University of Illinois. 31P[1H] NMR spectra were obtained on an NSF-250 spectrometer.

Single crystals were grown by the slow diffusion of diethyl ether into a solution of I in dichloromethane. A yellow crystal, 0.30 x 0.35 x 0.36 mm, was mounted on a fiber. Intensities were measured on a Nicolet R3m/\mu diffractometer using the \( \omega \)-scan technique, scan speed varied 5-20 deg. min$^{-1}$. The unit cell was determined from the least-squares analysis of angle data for 25 reflections with \( 19 < 20 < 26^\circ \). Data were collected to (sin \( \theta \))/\( \lambda \) of 0.65 \text{~A}^{-1}, \( h, k, l \leq 1 \). Three standard reflections collected every 197 reflections decreased less than 2% over data collection. Corrections to the intensity data for Lorentz effects, absorption (empirical) and for decay were applied. A total of 7785 reflections were measured with 7374 unique (\( R_{\text{int}} = 1.86 \% \)) and 4141 observed reflections with \( F_0 < 40 \text{~F} \). The structure was solved by direct methods which provided the location of one heavy atom (Ru) and four initially confusing peaks of apparent Z greater than P, S, or Cl that proved to be the Br atoms of the two positionally disordered molecules of Cl$_2$Br$_2$. The remaining nonhydrogen atoms were obtained from subsequent difference Fourier syntheses. The final refinement model incorporated a rigid, planar hexagonal constraint to the B-bound phenyl rings, and the C-Br distances were collectively refined to a common value of 1.86(1) \text{~A}. All nonhydrogen atoms were refined with anisotropic temperature factors, and the hydrogen atoms were included as idealized, isotropic contributions, but were not refined. For a total of 567 parameters, \( R = 0.0748, R_a = 0.0714, S = 1.407 \). Final (\( \Delta f \))$_{\text{max}}$ < 0.09 ca$^2$ on the final difference map. All calculations were performed on a Nicolet Corp., Madison, WI.

RESULTS

Crystal data are given in Table 1. The structure of \( \text{[Ru(CO)}(\text{PPh}_2\text{SC}_1\text{H}_7)]_2\text{Cl}_2 \)·2CH$_2$Br$_2$, I, is seen in Fig. 1. Atomic and equivalent thermal parameters are given in Table 2. Selected bond distances and angles can be seen in Table 3.
Figure 1. Structure of [Ru(CO)][PPh3SC12H2]2Cl2 showing atom labeling scheme. The hydrogen atoms have been omitted and the phenyl rings are shown as ipso atoms for clarity. Thermal ellipsoids drawn by ORTEP represent 35% probability surfaces.

DISCUSSION

The addition of CO results in the breaking of one of the Ru-S bonds in [Ru(CO)][PPh3SC12H2]2Cl2 and causes a rearrangement of the phosphines from the all cis configuration to a trans geometry, as seen in the structure of I (Fig. 1). One of the phosphine ligands remains chelated through the thioiphen sulfinyl. The Ru-S bond distance of 2.425(3) Å is slightly longer than the two comparable distances in [Ru(P(p-tolyl)2SC12H2)2Cl2]: Ru-S1, 2.345(5); Ru-S2, 2.402(5) Å (Bucknor et al., 1984). The pyramidal nature of the coordinated sulfur is evident by the angle defined by Ru-S2-C(1) (midpoint) of 131.8° in I compared favorably with the two independent angles (132.0° and 130.1°) in [Ru(P(p-tolyl)2SC12H2)2Cl2] (Bucknor et al., 1984). In the [Ru(thtCp)(PPh3)2Cl2] complex, the Ru-S-C midpoint angle is 126° and the Ru-S bond distance is 2.408(1) Å (Draganjac et al., 1995). The pyramidal nature of the thioiphen sulfinyl sulfur atom is also evident in the Cpd(CO)2DBT* (Goodrich et al., 1987) and Cpd* [Cr2=DBT] (Rao et al., 1991a) complexes. Angelici (1990) and Rauchfuss (1991) have reviewed structural aspects of thioiphen coordination.

Reflexing actinonitrile solutions of I in the presence of trime-thylamine oxide for 24 hrs did not result in decarbonylation. This fact and the ease of thiophen displacement by CO may be relevant to the CO poisoning of the HDS catalysts (Lombardo et al., 1980).

SUPPLEMENTAL MATERIAL

Anisotropic Thermal Parameters, Positional Parameters for the Hydrogen Atoms, Bond Lengths and Angles, and Structure Factor Tables (25 pages) are available from the authors upon request.
LITERATURE CITED


DOCUMENTED AIDS CASES AS THE BASIS FOR PROJECTIONS OF ADOLESCENCE HIV INFECTIONS IN THE U.S.

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ABSTRACT

Twenty percent of AIDS cases in the U.S. occur in individuals in the age range 20 to 29. The mean incubation time, the time from infection to the onset of AIDS, is in the order of 8 years. Therefore, most of these AIDS cases represent HIV infections that occurred during mid- to late-adolescence. About 800 officially reported cases in the age group 13 to 19 have occurred in the U.S. This low occurrence of AIDS should not be a source of complacency in assessing the need to provide education and behavioral alternatives to this age group. As the predominant mode of transmission of HIV infection shifts from gay-male behaviors and intravenous drug abuse (IVDA) to heterosexual intercourse, adolescents may be at significantly increased risk. The occurrence of STDs and early pregnancies indicate a significant rate of high-risk sexual behaviors in adolescents in the U.S. The rate of adolescent HIV infections can be projected by extrapolation from historical data and by epidemiological modeling and computer simulation. The rates of infection projected by these methods are sufficiently congruent to lend credibility to them. A rate of new HIV infections, in individuals in the age range of 13 to 19, in the order of 300,000 annually should be anticipated within the next 10 years.

INTRODUCTION

Most early estimates of the future incidence of AIDS were based on an unbounded geometrical increase in the number of diagnosed cases (Denning, 1988). Extrapolation from existing data is one means of projecting the future levels of AIDS cases. Historical trends in AIDS incidence are reported by the Centers for Disease Control (CDC) (Centers for Disease Control, 1992). The CDC considers delays in reporting and uses curve smoothing techniques (Karon et al., 1989).

We note that since the population susceptible to HIV infection is finite, it is not possible to have an unlimited growth in numbers of infected individuals. Growth curve should be logistic or sigmoid in form. Such growth curves are familiar in population modeling (Burghes, 1980) and epidemiology (Lilienfeld & Lilienfeld, 1980).

Epidemiological models and their corresponding computer-based simulations also can be used to determine the effects of varying assumptions concerning the mechanisms for the spread/containment of the AIDS pandemic. We consider populations susceptible to AIDS, sub-populations of the general population, to be distinct classes within which the number of AIDS cases propagate. Transmission categories allowed definition of discrete susceptible populations for which independent growth curves can be calculated. Since cross-over between these populations occurs, it is necessary to provide for dynamic interactions between them in the calculation of total incidence rates.

The starting point for our projections of future rates of HIV infections in adolescents was the observation that twenty percent of U.S. AIDS cases occur in individuals in the age range 20 to 29. Since the mean incubation time to the onset of full-blown AIDS is in the order of 8 years, most of these AIDS cases represent HIV infections that occur during mid- to late-adolescence.

METHODS

CONSTRAINTS ON MODELING IMPOSED BY LIMITED DATA

The principal source of data concerning AIDS in the United States is the United States AIDS Program, Center for Infectious Diseases, CDC. This agency publishes a monthly "HIV/AIDS Surveillance Report," which comprehensively covers the cases of AIDS reported in the United States. These CDC reports are carefully annotated to show limitations on the accuracy and validity of the data. Other sources of information include such agencies as the U.S. Department of Defense, which maintains detailed records for all military personnel and dependents, and the World Health Organization (WHO) which coordinates global HIV/AIDS data (Chin, et al., 1990).

AIDS cases, reported by age at time of diagnosis, are shown in Figure 1. We focus here on the age groups 13-19 and 20-29. The age group 13-19 includes 789 AIDS cases (of a total of 206,392 reported by the CDC in January, 1992). This small number has been the basis for an argument that resources need not be dedicated to prevention programs targeted to this age group. When we examine the age group 20-29, however, the number of AIDS cases is clearly significant at 40,362. We will argue in this paper that these numbers indicate a high occurrence of new HIV infections in the age group of 13-19. We will project HIV infection rates for 13-19 year old individuals using both extrapolations from historical data and a transmission-based epidemiological model and computer simulation.

![Figure 1. AIDS cases by age at time of diagnosis as reported by the Centers for Disease Control, January, 1992.](image-url)
EXTRAPOLATION FROM HISTORICAL DATA

Using CDC data tabulated by age at time of diagnosis, we constructed a graph of the accumulated number of AIDS cases by age distribution (shown as the solid line in Figure 2). Using the working assumption of a mean interval between seroconversion and the onset of full blown AIDS of 8 years, we then constructed an average line for accumulated HIV infections also by age distribution (shown as the broken line in Figure 2).

Figure 2: Accumulated Number of HIV Infections and AIDS Cases Displayed as a Function of Age at time of Infection or Diagnosis.

By linear interpolation we then computed the distribution of HIV positive cases according to the age groupings used by the CDC. This distribution is shown as solid bars in Figure 3. To assist in comparing the distributions, we included in Figure 3 the age distributed AIDS cases shown in Figure 1.

An additional extrapolation is required. Since the CDC reports quarterly the number of AIDS cases diagnosed, we cautiously use these data for a near term extrapolation of future trends. This extrapolation is shown in Figure 4. In this admittedly simplistic approach, we assume three rates of growth: 5, 10, and 15% compounded. We use the lowest rate (5%) for comparison with results obtained by modeling and simulation that we describe in the following section.

Figure 4: Historical and Extrapolated Quarterly AIDS cases in the U.S.

We agree with the CDC that the smoothed curve that they develop from these data "should be considered a description of the overall trend in AIDS cases but predictions of future numbers of cases should not be made by extrapolating the curve." The CDC further notes that "This curve emphasizes that the rate of increase in the incidence slowed during the middle of 1987." (CDC, 1992). On the basis of results obtained by modeling and simulation, we strongly suspect that this slowing is the result of reduced numbers of susceptible individuals in the most heavily impacted behavioral categories in the late 1980s, that is, homosexual males and intravenous drug abusers (IVDUs). We anticipate a resumption of the earlier trend in increasing rates as the epidemic moves to the larger heterosexual population.

Many other methods for projecting future trends in the AIDS epidemic have been reported (Brookmeyer & Damiano, 1989; Gail, 1990; Gruttola, et al, 1989). To our knowledge, however, none have previously studied explicitly the problem of projecting HIV infection rates in adolescents.

EPIDEMIOLOGICAL MODELING AND COMPUTER SIMULATION

The basic transmission-based epidemiological model for HIV/AIDS used in this study consists of three main steps:

(Step 1) Calculate the number of newly infected persons in each population class or category for the interval.

(Step 2) Calculate the changes in sub-populations (net growth or decline).

(Step 3) Update the population census and reiterate.

These steps are incorporated into the model (Goforth, 1989) that is depicted schematically in Figure 5.

We define the number of persons currently infected to be equal to the number infected in the previous interval plus the number of newly infected, minus the number of deaths. One significant working assumption for this study was a mean interval between seroconversion and the onset of AIDS of 8 years. Further, we assumed this to be the same for males and females for ages above 12 (Chin, 1990).
Since the U.S. population of IV drug abusers is relatively small part of the total population and since such a high proportion of that population is already infected, we choose to use a curve-fitting approach to establish the contribution of that population to the AIDS census. Further, we calculate the number of pediatric HIV infections (defined here as patients under age 13) by using natality tables and age-distributed cohorts of HIV+ heterosexual females.

There is a considerable sensitivity of the cumulative number of AIDS deaths to uncertainties in behavioral and transmission factors. The probable impact of the introduction of vaccines of varying degrees of effectiveness in inoculation programs with differing start dates and durations also may be determined using the model shown in Figure 5 (Goforth, 1990). The ability of an epidemiological model to accommodate these calculations makes it a useful tool in establishing allocation of AIDS treatment/prevention resources.

RESULTS

CONGRUENCE OF PROJECTED RATES OF ADOLESCENT HIV INFECTIONS

The results of our projections, derived by both extrapolation from historical data and by modeling/simulation, are shown in Figure 6. We find that the rates of infection projected independently by these methods are sufficiently congruent to lend credibility to them. The trend to increased rates of infection will continue. A rate of new HIV infections, in individuals in the age range of 13 to 19, in the order of 300,000 annually should be anticipated within the next 10 years.

We estimate the range of uncertainty in these projections to be high, increasing from about ±20% in the 1993 projection to about ±40% in the 2001 projected rate. These estimates of uncertainty were derived by pushing the model/simulation with a range of input values for transmission risks, rates of partner change, and latency periods.

DISCUSSION

ADDITIONAL EXAMINATION OF THIS PROBLEM IS REQUIRED

Within the U.S. there are significant differences in the incidence of AIDS in different geographical areas, age groups, and socioeconomic groups. The original model has been extended to accommodate these non-homogeneities and an algorithm has been devised for handling the migration of persons either between geographical areas or between age and socioeconomic groups. This algorithm appears to have utility and we have used it to explore the implications of population interactions and migrations on the spread of HIV/AIDS in the Southwest Pacific region (Goforth, 1990).

It is important to realize that many factors influencing the epidemiological model are not independent. Indeed, many interactions add significantly to the complexity of the resulting computer code. The code is modular, however, and each factor can be independently analyzed.

An example of a detailed calculation that could push the computation time beyond what is operationally acceptable for an interactive simulation system is the full inclusion of probabilistic data for the AIDS latency period. It is straight forward to use mean values for the latency period, e.g. 6.5 years for females and 7.8 years for males, but clearly the actual situation is complex and should be modeled in more detail if adequate data were available. Compounding this problem is how "entities" are defined for the simulation. The "entities" may represent individual members of small sub-populations or perhaps 1,000 or 10,000 individuals for members of large sub-populations. This contrasts markedly with the use of probabilistic data for the "risk of transmission" and "rate-of-partner-change" data where aggregated factors may be applied to the whole sub-population rather than individuals.


It is important to take note of some significant differences that distinguish the age group of 13-19 year olds for either younger or older age groupings. There are few HIV infected individuals entering the 13-19 year age grouping by cohort aging. Pediatric cases, particularly victims of perinatal infection, do not survive to become 13 year olds. This is the main reason for the relatively low occurrence of AIDS in 13-19 year olds.

There are about 3 million cases of STDs in 13-19 year olds reported annually in the U.S. This is one indicator of high-risk behaviors but, of equal significance, it is one that suggests that a pathway for infection exists in this age group that increases the likelihood of transmission per exposure. Other indicators of high-risk sexual behaviors are found in age differentiated birth rates and reports of sexual behaviors and attitudes. We note that self-reporting studies show that about one-half of public school students in grades 9 through 12 in Arkansas are sexually active.
The risk of HIV infection in this age group is likely to be substantially increased by exploitative contacts with partners from older subpopulations. We did not, yet, attempt to estimate this effect on projected infection rates.

The occurrence of IVDA in the 13-19 year old age group is not well documented. As a working assumption we took the IVDA rate to be 25% of that for the aggregated 20-45 year age group.

CONCLUDING REMARKS

There are a number of uses for simulation as a tool in forecasting related to the AIDS pandemic. The very nature of computer simulation and modeling demands clear definitions of the problems, working assumptions, input data, and relationships (mathematical). Good modeling requires objectivity and is generally intolerant of hidden agendas. Simulation provides a mechanism for sensitivity analyses. It is also a tool for handling the computations associated with systems with complex interactions and described in statistical terms.

Concerning the AIDS pandemic in the U.S., we note that as the predominate mode of transmission of HIV infection shifts from gay-male behaviors and IVDA to heterosexual intercourse, adolescents may be at significantly increased risk. Further, the occurrence of STDs and early pregnancies indicate a significant rate of high-risk sexual behaviors in adolescents in the U.S.

We have projected the rate of adolescent HIV infections by both extrapolation from historical data and by epidemiological modeling and computer simulation. We find that the rates of infection projected by these methods are sufficiently congruent to lend credibility to them. The annual rate of new HIV infections, in individuals in the age range of 13 to 19, in the order of 300,000 should be anticipated within the next 10 years. The low occurrence of AIDS in individuals 13 to 19 to date should not be a source of complacency in assessing the need to provide education and behavioral alternatives to this group.

The impact of under-reporting of AIDS was not considered. We note, however, that to the extent that under-reporting is significant, our projections are low.

LITERATURE CITED


THE SCHROEDINGER EQUATION WITH SPHERICALLY AVERAGED POTENTIALS

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ABSTRACT

Using a method adapted from few—body hyperspherical techniques, an approach to the solution of the Schrödinger equation with nonspherical potentials is discussed. The method is to spherically average the potential over spherical angles and then solve the resulting set of coupled differential equations. A discussion of how this method is applied to the Stark effect is presented.

INTRODUCTION

The method for obtaining the solution of the three dimensional time—

independent Schrödinger equation for a spherically symmetric potential is straightforward. It generally involves successively applying the method of separation of variables until a pure radial solution is obtained. This can be solved either analytically or numerically depending on the nature of the potential.

The case of a nonspherical potential is more difficult. Traditional approaches have relied primarily on perturbation theory. What is presented here is an alternative approach adapted from few—body hyperspherical techniques. For comparison, a discussion of the Schrödinger equation in a spherical potential is first presented. This is followed by a presentation of the spherical averaging approach to the Schrödinger equation in a nonspherical potential. Last, it is demonstrated how this approach can be applied to the problem of the linear Stark Effect.

THE SCHROEDINGER EQUATION WITH
A SPHERICAL POTENTIAL

A nonrelativistic, quantum mechanical system of two point objects
interacting through some space two—body interaction \( V(r_1—r_2) \) is represented by the time—
independent Schrödinger equation as

\[
\left[ -\frac{\hbar^2}{2m_1} \frac{\partial^2}{\partial r_1^2} - \frac{\hbar^2}{2m_2} \frac{\partial^2}{\partial r_2^2} + V(r_1—r_2) \right] \psi(r_1,r_2) = E_{\text{tot}} \psi(r_1,r_2).
\]

The coordinates \( r_1 \) and \( r_2 \) represent the position of each particle with respect to any arbitrarily chosen origin. Since the force of interaction depends only on the relative position \( r_1—r_2 \), equation (1) can be separated into two equations by introducing a center of mass coordinate (2) and a relative coordinate

\[
(2) \quad R = \frac{m_1 r_1 + m_2 r_2}{m_1 + m_2}
\]

and a relative coordinate

\[
(3) \quad r = r_1 — r_2.
\]

The two—body wave function is taken to be the product of a center of mass wave function, \( \psi(R) \) and a relative wave function \( \psi(r) \):

\[
(4) \quad \psi(r_1,r_2) = \psi(R) \psi(r).
\]

The resulting center of mass equation

\[
(5) \quad \left[ -\frac{\hbar^2}{2(m_1 + m_2)} \frac{\partial^2}{\partial R^2} + \frac{1}{m_1 + m_2} \right] \psi(R) = E_{\text{cm}} \psi(R)
\]

represents the motion of the center of mass relative to the arbitrary origin and its solution is a plane wave. The relative equation, which contains the interaction between the two particles

\[
(6) \quad V(r_1—r_2) = V(r) = V(r_1, \theta_1, \varphi_1),
\]

reduces to an effective one—body equation

\[
(7) \quad \left[ -\frac{\hbar^2}{2m} \frac{\partial^2}{\partial r^2} + V(r) \right] \psi(r) = E \psi(r).
\]

Here, \( m = m_1 m_2/(m_1 + m_2) \) is the reduced mass and \( E = E_{\text{tot}} — E_{\text{cm}} \) is the relative energy. This last equation can be simplified further by writing the \( \nabla \) operator in terms of a radial derivative and the angular momentum operator \( L^2 \) (Goswami, 1992) as

\[
(8) \quad \left[ -\frac{\hbar^2}{2m} \frac{\partial^2}{\partial r^2} + L^2 + V(r) \right] \psi(r) = E \psi(r).
\]

In order to solve equation (8), it is necessary to know the form of the interaction \( V(r) \). The most common application is to use a "spherically symmetric potential" that is independent of the angular coordinates \( \theta \) and \( \varphi \):

\[
(9) \quad V(r) = V(|r|) = V(r).
\]

For this case, a wave function that is a product of a purely radial wave function \( R(r) \) and a purely angular wave function \( Y(\theta, \varphi) \) is assumed:

\[
(10) \quad \psi(r) = R(r) Y(\theta, \varphi).
\]

Upon substituting this in eq. (8), with the potential chosen as in eq. (9), separate equations describing the radial and angular motion are obtained.

The angular equation takes the form

\[
(11) \quad L^2 Y(\theta, \varphi) = -\hbar^2 \left[ \frac{1}{\sin \theta} \frac{\partial}{\partial \theta} \sin \theta \frac{\partial}{\partial \theta} + \frac{1}{\sin^2 \theta} \frac{\partial^2}{\partial \varphi^2} \right] Y(\theta, \varphi) = \ell(\ell+1)\hbar^2 Y(\theta, \varphi),
\]

where \( \ell(\ell+1) \) is the separation constant between the two equations and \( \ell \) is called the angular momentum quantum number. This angular equation can be reduced one more time into separate equations for the \( \theta \) and \( \varphi \) motion by writing \( Y(\theta, \varphi) \) as a product of wave functions for each of the two angular coordinates (Arfken, 1985). Here the separation constant is \( m \), the azimuthal quantum number. Once these angular equations are solved, the product of the solutions is known as a spherical harmonic and is indexed to indicate its dependence on the two separation constants as \( Y_m(\theta, \varphi) \). The angular momentum quantum number \( \ell \) takes on integer values from zero to infinity and, for each \( \ell \), the azimuthal quantum number \( m \) takes on values from \( -\ell \) to \( +\ell \).

The radial equation, the only equation carrying information describing the force between the two particles, now takes the form

\[
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\]
The Schroedinger Equation With Spherically Averaged Potentials

In obtaining the radial equation (12) from eq. (8), it was assumed that the potential was spherically symmetric. If the potential in eq. (8), instead of being just a function of \( r \), has some kind of multiplicative angular dependence as well, then the method of separation of variables described above runs into trouble. Fortunately, in any given realistic problem, the dominant force is usually radial in nature and any extra nonspherical components are written as smaller terms added to it. The traditional method for handling these types of forces is with perturbation theory (Winter, 1986).

An alternative approach to standard perturbative techniques is based on a method adapted from few-body hyperspherical techniques (Frolov, 1986; Fabre De La Ripelle, 1979; Larsen, 1986; Ban, et al. 1972). The spherical harmonics obtained by solving eq. (11) represent a complete set of angular basis functions for any function of \( \theta \) and \( \varphi \). This means that any function of \( \theta \) and \( \varphi \) can be expanded in a series of these basis states (Arfken, 1985):

\[
\psi(r, \theta, \varphi) = \sum_{l=0}^{\infty} \sum_{m=-l}^{l} R_{l} m(r) Y_{l} m(\theta, \varphi).
\]

This results in a slightly more complicated form for the radial equation than was observed in eq. (12):

\[
\left[-\frac{\hbar^2}{2\mu} \frac{d^2}{dr^2} + \frac{\ell(\ell+1)\hbar^2}{2\mu r^2} + V(r)\right] R_{l}m(r) = E R_{l}m(r).
\]

THE SCHROEDINGER EQUATION WITH NONSPHERICAL POTENTIALS

In obtaining the radial equation (12) from eq. (8), it was assumed that the potential was spherically symmetric. If the potential in eq. (8), instead of being just a function of \( r \), has some kind of multiplicative angular dependence as well, then the method of separation of variables described above runs into trouble. Fortunately, in any given realistic problem, the dominant force is usually radial in nature and any extra nonspherical components are written as smaller terms added to it. The traditional method for handling these types of forces is with perturbation theory (Winter, 1986).

An alternative approach to standard perturbative techniques is based on a method adapted from few-body hyperspherical techniques (Frolov, 1986; Fabre De La Ripelle, 1979; Larsen, 1986; Ban, et al. 1972). The spherical harmonics obtained by solving eq. (11) represent a complete set of angular basis functions for any function of \( \theta \) and \( \varphi \). This means that any function of \( \theta \) and \( \varphi \) can be expanded in a series of these basis states (Arfken, 1985):

\[
\psi(r, \theta, \varphi) = \sum_{l=0}^{\infty} \sum_{m=-l}^{l} R_{l} m(r) Y_{l} m(\theta, \varphi).
\]

Although the radial functions are as yet unknown, they will in general depend on three quantum numbers, unless some symmetry removes that dependence, as was observed for the radial solution of eq. (12). For our case, the quantum numbers will be \( l \) and \( m \) (shown explicitly above) and a principal quantum number \( n \) (not shown) which will again be associated with the energy.

Upon substituting eq. (14) into eq. (8) and allowing the angular momentum operator to operate onto the spherical harmonics in the sum as

\[
\sum_{l,m} R_{l} m(r) Y_{l} m(\theta, \varphi) = \sum_{l,m} R_{l} m(r) Y_{l} m(\theta, \varphi),
\]

the Schroedinger equation becomes

\[
\frac{\hbar^2}{2\mu} \frac{d^2}{dr^2} \sum_{l,m} R_{l} m(r) Y_{l} m(\theta, \varphi) + \frac{\ell(\ell+1)\hbar^2}{2\mu r^2} \sum_{l,m} R_{l} m(r) Y_{l} m(\theta, \varphi) + \sum_{l,m} V(r) Y_{l} m(r) R_{l} m(r) = E \sum_{l,m} R_{l} m(r) Y_{l} m(r).
\]

This equation can be simplified by multiplying on the left by the complex conjugate of a spherical harmonic \( Y^*_{l m} \) integrating each term over the solid angle

\[
d\Omega = d(\cos \theta) d\varphi
\]

and applying the orthonormality condition of the spherical harmonic basis functions (Arfken, 1985):

\[
\int Y_{l m}^* Y_{l' m'} d\Omega = \delta_{l l'} \delta_{m m'},
\]

AN EXAMPLE: THE LINEAR STARK EFFECT

In the case of the simple hydrogen atom, an electron is assumed to move in the Coulomb potential generated by a proton

\[
V_e = -\frac{e^2}{r},
\]

where \( e \) is the magnitude of the electron charge and \( k = \frac{\hbar^2}{m} \). This force is purely radial and the solution to eq. (12) can be obtained analytically by a series solution (Winter, 1986). When an external electric field \( \mathbf{E} \) is applied to a hydrogen atom, and the \( z \)-axis is chosen to point along the direction of the applied field, the interaction potential has the form (Mizushima, 1970)

\[
V_{\text{ext}} = -e \mathbf{E} \cdot \mathbf{r} = -e \mathbf{E} \cos \theta.
\]

The total potential is the sum of eq. (20) and eq. (21), a problem known as the linear Stark Effect. Again, the traditional approach to this problem is to solve eq. (12) for the Coulomb states and then use these states with perturbative techniques to diagonalize \( V_{\text{ext}} \). Of interest here is the spherical averaging alternative to this approach. For this example, eq. (19) can be written as

\[
\sum_{l,m} \left[ \int Y_{l m}(\theta) \cos \theta d\theta \right] \int Y_{l m}^* Y_{l' m'} d\Omega = \delta_{l l'} \delta_{m m'}
\]

and then applying the identity (Goswami, 1992)

\[
\int Y_{l m}^* Y_{l m}^* d\Omega = \frac{(2\ell+1)!(2\ell'+1)!}{4\pi(2\ell+1)!} (\ell' \ell m l m > \ell' \ell 0 0 \ell 0 0)
\]

The two Clebsch-Gordan (CG) coefficients on the right hand side have
values that are related to the coupling of angular momenta. The CG coefficients have properties that will cause them to be zero for certain values of the quantum numbers. In particular, the arbitrary CG coefficient $\langle \ell_m, \ell_{m'} | \ell_{m''} \rangle$ will vanish unless: 1) $m + m' = m''$ and 2) $\ell$ can vectorially couple to $\ell$ to produce $\ell$. In addition, CG coefficients of the form $\langle 0 \ell | 0 \ell \rangle$ will vanish unless: 3) $\ell + 1 = \ell$ is an even integer.

In this case, with $M=0$, the first condition means that $m = m''$ for every one of our radial equations. The second condition, with $L=1$, means that the sum in eq. (22) can only couple the $L+1$ state, the $L$ state, and the $L-1$ state to the change in the $L$ state. Applying the third condition causes the coupling of the change in the $L$ state to its own partial wave to vanish. Finally, the radial equation takes on the simplified form

$$
(2m + 1) \frac{d}{dr} \left[ r^{2l+1} \frac{d}{dr} \right] \alpha_{\ell m} - E \alpha_{\ell m} = \frac{\ell (\ell + 1)}{2} \alpha_{\ell m} - \delta \delta [\alpha_{\ell m} R_{\ell-1 m} + \beta_{\ell m} R_{\ell+1 m}] = E \beta_{\ell m}
$$

where the coefficients $\alpha_{\ell m}$ and $\beta_{\ell m}$ are defined by

$$
\alpha_{\ell m} = \frac{\ell (\ell + 1) [2l+1]}{2(2l+1)}
$$

and

$$
\beta_{\ell m} = \frac{\ell (\ell + 1) [2l+1]}{2(2l+1)}.
$$

The $\alpha$ and $\beta$ coefficients have the interesting property that $\alpha_{\ell m+1 m} = \beta_{\ell m}$.

The solution to the Stark effect still requires solving an infinite number of equations, but at least the equation for a given partial wave only couples to the partial wave immediately before and immediately after it. In any case, only the lowest angular momentum states are of interest anyway. The scheme, then, is to solve the system of equations truncated at $\ell = 3$, then $\ell = 4$, then $\ell = 5$, and so on, until the solutions for the lower angular momentum states converge to the same values for successive iterations. The strength of the interaction and desired accuracy for a certain partial wave state will determine how many equations must be simultaneously solved before the system can be truncated. Work is currently under way to numerically solve these linear Stark effect equations and will be reported elsewhere.

**CONCLUSIONS**

It has been demonstrated that, for the Schroedinger equation in nonspherical potentials, there is an alternative to perturbative techniques which has been adapted from few—body hyperspherical techniques. This technique, the method of spherical averaging, requires the solution of a large set of coupled differential equations. The size of the set of equations depends upon the strength of the potential and the highest partial wave solution desired. For this reason, it is probably not very competitive with standard perturbation theory, although this remains to be tested. At the very least, this alternative method offers insight into the few—body hyperspherical method, now achieving prominence in several fields of physics where similar approaches are becoming, in many instances, the preferred method and, in certain cases, the only method available (Larsen, 1986; Bas et al., 1972).

**LITERATURE CITED**


MEASURING SHRUBLAND VEGETATIONAL STRUCTURE USING AVIAN HABITATS AS AN EXAMPLE

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ABSTRACT

Vegetational sampling of avian habitats stresses the use of methods primarily designed for forest birds. This paper describes a technique for sampling vegetational structure in uneven patchy habitats such as shrublands. Using the method, avian habitats in old field shrublands of northwestern Arkansas were analyzed.

INTRODUCTION

The sampling of vegetational structure in avian ecological studies has stressed forest habitats and forest birds (James and Shugart, 1970) or ignored fine details emphasizing instead overall characteristics of vegetation (MacArthur and MacArthur, 1961). Because of the uneven character of shrubland vegetation produced by the mosaic pattern of alternating patches of grasses, shrubs and small trees, the task of measuring vegetational structure in this habitat is especially challenging. Early successional old fields and various scrub and shrubland associations are examples of this type of environment. I have been studying avian microhabitats in these environments on four continents and found it necessary to adopt a method for sampling vegetational structure that was suited to this unique situation. This study describes the sampling technique I developed and used. It is designed to determine the fine structure of old field shrubland vegetation and also depict overall configurations. The example of its use that is presented is the analysis of avian habitats in old fields of northwestern Arkansas.

MATERIALS AND METHODS

Positions of birds encountered in the field were marked and these points became centers of circular plots measuring 14.6 m in radius, thus equalling 669.7 square meters. Within these plots 11 vegetational factors were measured. The height of the tallest tree or bush in the plot was recorded. Also, an estimate of the average vegetation height was obtained from several measurements throughout the plot using a calibrated pole. The calibrated metal pole was 3.0 m long and 10 mm in diameter, and was marked off into 0.6 m intervals. The 0.6-m intervals were accentuated using different colored paints. The pole was positioned vertically from the ground at random points in the plot and the total numbers of leaves touching it in each of the 0.6-ft intervals were recorded in the following eight sections: 0.0-0.6 m, 0.6-1.2 m, 1.2-1.8 m, 1.8-2.4 m, 2.4-3.0 m, 3.0-3.7 m, 3.7-4.3 m, and over 4.3 m. This constituted 8 vegetational factors. For making leaf counts above the 3-m height of the pole, the pole was lifted overhead to appropriate heights. For the unusual very high trees leaves were counted using an overhead range finder.

There were a total of 40 random pole positions used in counting leaves. These were distributed in four orthogonal line transects originating at the center point of the plot, the first transect being defined by following the direction indicated by a random twirl of a compass dial. Ten random pole positions were located in each of the four transects. The total leaf counts for the plot in each of the 0.6-m intervals was obtained by summing across all forty pole positions for each interval. The 11th and final factor measured was the count of all live woody stems, regardless of size, encountered along each of the four line transects and summed to give a total for the plot. The stem count was made in a 0.3-m wide band along the transects at a height of 1.2 m.

From the vegetational factors measured in the field five additional factors were calculated. These added ones pertained to vegetational patterns. Four of the added factors indicated degree of evenness in the vegetation. These all were based on the commonly used measure J' for expressing evenness in ecological communities (Pielou, 1975),

\[ J' = \frac{H'_\text{max}}{H'} \]

where \( H'_\text{max} \) is the log of the number of categories under consideration and \( H' \) is the Shannon index for diversity,

\[ H' = -\sum p_i \log p_i \]

in which this case \( p_i \) is the proportion of the total vegetation existing in each category. Evenness has been used in studies of vegetational pattern (Pielou, 1966), high values of \( J' \) indicating an even distribution of vegetation, low values being associated with uneven or patchy mosaic patterns.

Foliage vertical evenness was a pattern factor that summed the total leaves in each 0.6-m level across all 40 sample points. The parameter \( p_i \) then became the proportion of the grand total number of leaves (N) that occurred in each of the levels (\( p_i = n_i/N \), where \( n_i \) is the number of leaves in the ith level). High diversity and evenness existed when the leaves were uniformly distributed through all strata, low values were associated with uneven distributions between vertical strata. Foliage coarse grained horizontal evenness was calculated using total leaves in each of the four transects summed across all strata, representing the proportion of the overall total number of leaves that occurred in each transect. This produced a measure relating to the distribution of vegetation from sector to sector over the circular sample plot, a low evenness value showing a very patchy distribution of vegetation between sectors, a high value indicating an uniform density in vegetation from place to place in the plot. Foliage fine grained evenness used the total number of leaves touching the pole at each of the 40 random pole-sample positions. The parameter \( p_i \) was the proportion of leaves found at the ith random position compared to the total number of leaves counted over the whole plot. In this case a low evenness value was associated with a highly irregular pattern of vegetation density from place to place within sectors of the plot as well as between sectors. High values of evenness indicated a uniform rather than patchy pattern of vegetation on a fine scale from place to place in the plot.

Stem evenness represents the pattern of shrubbiness in the sample plot, where \( p_i \) is the proportion of total stems occurring in each of the 4 transects. High values show an even distribution of low woody vegetation throughout the plot, low values indicate an irregular patchy pattern of shrubs. The measure of stem variability was calculated by summing the absolute values of the differences in number of stems between successive transects in the plot. This was not adjusted for relative number of stems in the sample plot so the calculation of \( H' \) and \( J' \) was not performed in this case. Starting with a transect, the number of stems in that transect was subtracted from the number in the adjacent transect in the circle. The absolute value of that difference was then summed with the absolute value of the difference between the second transect and its adjacent one in the circle, and so forth until four such values were totaled from the four transect comparisons. If this index of stem variability was high it showed that there was considerable variation.
in shrubbiness between sectors in the plot circle, a low value indicated the existence of a rather uniform shrubbiness throughout the plot.

In addition to the plots around bird locations a series of samples were obtained the centers of which were randomly determined. This provided a characterization of the overall habitat in which the birds occurred, and served for comparison to the microhabitats occupied by the bird species. Because this technique has been employed by me on several continents and it was never possible to find poles of the same diameters in these diverse places, each pole used was standardized to a string line vertically suspended by a light plumb through the vegetation. This essentially represented a dimensionless point piercing the vegetational structure. To perform the standardization the measuring pole was positioned and the leaves counted in each 0.6-m interval. Then a longer pole was anchored in the ground at a slant with a string line and plumb attached to its tip. This pole was carefully positioned so that the string line dropped right next to the measuring pole. Next the measuring pole was moved to the side so that the string line took up its position. The leaves touching the string line were counted in the 0.6-m intervals using the nearby pole as a measuring guide. Of course the string line touched fewer leaves than the wide-diametered pole. The conversion needed was calculated by dividing the total number of leaves touching the string by the total touching the pole. This was repeated for a number of pole positions to obtain an average of the conversion ratio. When compiling the data obtained using this pole the leaf count totals per stratum were multiplied by the conversion factor to produce a standardized value converted to string line measurements. In the case of the study in old fields of northwestern Arkansas reported here the conversion factor was 0.6. Thus the pole leaf counts were multiplied by this value to standardize them.

RESULTS AND DISCUSSION

This method of vegetational sampling has been used in my studies of avian community ecology in shrubland habitats on a global scale in Ghana in West Africa (1970-1971), Nepal in South Asia (1981-1982), Belize in Central America (1983-1989), and North America in northwestern Arkansas in 1972 (Posey, 1974) plus northern Michigan beginning in 1987 and still in progress. An example of the kinds of results that are obtained are presented here (Table 1) portraying the

Table 1. Mean values for vegetational factors measured in shrubby old field habitats in northwestern Arkansas, comparing random samples with the habitats occupied by three bird species.

<table>
<thead>
<tr>
<th>Vegetational Factor</th>
<th>Random Sample</th>
<th>Meadowlark</th>
<th>Indigo Bunting</th>
<th>White-eyed Vireo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg. vegetational height (m)</td>
<td>1.0</td>
<td>0.9</td>
<td>1.1</td>
<td>2.2</td>
</tr>
<tr>
<td>Height tallest tree (m)</td>
<td>4.4</td>
<td>3.9</td>
<td>8.5</td>
<td>9.6</td>
</tr>
<tr>
<td>Total stems at 1.2 m height</td>
<td>21.9</td>
<td>12.5</td>
<td>26.8</td>
<td>39.1</td>
</tr>
<tr>
<td>Total leaves 0-0.6 m high</td>
<td>68.1</td>
<td>83.4</td>
<td>89.3</td>
<td>83.8</td>
</tr>
<tr>
<td>Total leaves 0.6-1.2 m high</td>
<td>17.3</td>
<td>16.6</td>
<td>13.7</td>
<td>27.0</td>
</tr>
<tr>
<td>Total leaves 1.2-1.8 m high</td>
<td>3.6</td>
<td>3.0</td>
<td>7.0</td>
<td>19.5</td>
</tr>
<tr>
<td>Total leaves 1.8-2.4 m high</td>
<td>2.6</td>
<td>1.9</td>
<td>5.3</td>
<td>17.5</td>
</tr>
<tr>
<td>Total leaves 2.4-3.0 m high</td>
<td>2.4</td>
<td>2.1</td>
<td>4.4</td>
<td>10.4</td>
</tr>
<tr>
<td>Total leaves 3.0-3.7 m high</td>
<td>2.1</td>
<td>1.7</td>
<td>7.7</td>
<td>10.8</td>
</tr>
<tr>
<td>Total leaves 3.7-4.3 m high</td>
<td>1.8</td>
<td>1.6</td>
<td>2.9</td>
<td>7.2</td>
</tr>
<tr>
<td>Total leaves above 4.3 m high</td>
<td>3.9</td>
<td>2.6</td>
<td>6.1</td>
<td>19.9</td>
</tr>
<tr>
<td>Foliage vertical evenness</td>
<td>0.42</td>
<td>0.41</td>
<td>0.46</td>
<td>0.74</td>
</tr>
<tr>
<td>Foliage coarse grained</td>
<td>0.30</td>
<td>0.28</td>
<td>0.39</td>
<td>0.93</td>
</tr>
<tr>
<td>Foliage fine grained</td>
<td>0.05</td>
<td>0.04</td>
<td>0.93</td>
<td>0.94</td>
</tr>
<tr>
<td>Stem evenness</td>
<td>0.31</td>
<td>0.33</td>
<td>0.75</td>
<td>0.93</td>
</tr>
<tr>
<td>Stem variability</td>
<td>17.0</td>
<td>13.0</td>
<td>23.6</td>
<td>46.2</td>
</tr>
</tbody>
</table>

Arkansas situation (Posey, 1974). In Table 1 the first column of figures are the mean values for each vegetational factor obtained from the random vegetational samples, thus representing an evaluation of the vegetational structure that existed in the study area. Compare these with the next three columns, which are the mean values for the same factors but in the microhabitats occupied by 3 bird species in the study area. The Eastern Meadowlark (Sturnella magna) occurs in the more open parts of the shrubland habitat, the White-eyed Vireo (Vireo griseus) occupies the most dense shrubby thickets, and the Indigo Bunting (Passerina cyanea) is between these extremes.

The three species shown in Table 1 are representative of a total of 17 species sampled in the Arkansas study (Posey, 1974). As an example of the kinds of analyses that can be made using this information, ordinary principal components ordination (Cooley and Lohnes, 1971) of the species in habitat space can be performed using the combined set of vegetational factors (Fig. 1). The first principal component (abscissa) was associated with degree of foliage density in the vegetational factors, open country to the left, dense shrubland to the right. Notice the positions of the 3 species mentioned above: the Eastern Meadowlark at the open grassland edge on the left of the ordination, the White-eyed Vireo far to the right in the thick shrubby environs, and the Indigo Bunting in between. The second principal component (ordinate) was heavily weighted on factors relating to horizontal evenness in foliage density, an even distribution of vegetation from place to place occurring at the top of the ordinate in Figure 1, an uneven vegetational mosaic pattern positioned at the bottom. Note that although both species occupied a habitat of medium vegetational density on the shrubbiness axis (Figure 1), the Bobwhite (Colinus virginianus) selected environs having a uniformly dense vegetation while the Brown Thrasher (Toxostoma rufum) occurred in habitats characterized by having scattered bare areas.

When conducting the study in the shrublands of Nepal near Kathmandu, the four field personnel involved in taking the samples performed an exercise designed to test an aspect of the reliability of the method. Each of the four investigators sampled the same plot for each of two plots, one plot in open country, the other in dense shrubland. From the four samples on a given plot, and comparing two of the samples at a time, coefficients of community similarity (Cox, 1985) were calculated for that plot using the respective values obtained for the 11 vegetational factors measured in the field. All permutations of the four samples on a plot produced six community similarity coefficients, or a total of 12 such coefficients from the two plots. The average of these 12 coefficients was 85%, which is far short of the perfect similarity value of 100% theoretically expected from replicate samples on the same plot. However, Cox (1985) points out that replicate samples of the same community commonly show similarity coefficients of around only 85%. Therefore, in this regard the method described here is comparable in reliability to other community sampling methods.
It should be noted that this method was developed in the late 1960s before the metric system of measurements was universally adopted in scientific publications. Therefore, English system units were used, and have continued to be used through the years for the sake of uniformity in data collection. Expressing the design of the method in metric units makes it look odd. To clarify things I now give the original English units used, which will assist those who want to perform vegetation analyses for comparison to my results. The radius of the plot was 48 ft. Therefore, the four transects were each 48 ft long. The pole used in counting leaves was 10 ft tall divided into 2-ft intervals; 0-2 ft, 2-4 ft, 4-6 ft, 6-8 ft, 8-10 ft, and was raised to count leaves at heights of 10-12 ft, 12-14 ft, and over 14 ft. The four narrow transects in which woody stems were counted were each 48 ft long and 1 ft wide.

LITERATURE CITED
LONG-TERM WHITE-TAILED DEER HARVEST TRENDS FOR THE SOUTHCENTRAL UNITED STATES

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ABSTRACT

White-tailed deer herd size across the southerncal states continues to increase. Concurrent with this increase has come a total harvest level increase for most states. Southerncal states have increased bag limits on antlerless deer to insure that herd health is maintained as herd sizes approach total carrying capacity. Harvest growth rates, however, show irregularities from year to year. The cyclic pattern of harvest (and population) growth rate is of shorter duration than would be expected in a large ungulate population. An exogenous influence is suspected. Cyclic patterns in harvest growth rates move opposite the growth rate of epizootic hemorrhagic disease incidence in southerncal counties. Initial results suggest causality between disease incidence and harvest growth rate. As herds approach carrying capacity on many southern sites, management challenges increase.

INTRODUCTION

Harvest data and their interpretation are an integral component of white-tailed deer (Odocoileus virginianus) management. Harvest data are usually compiled by state game agencies and used as a basis for recommending future harvest regulations. Recommending and setting harvest regulations are often controversial subjects, especially considering the diversity of public expectations which results from a variety of different attitudes and varying degrees of past management success. Several studies have reported on relatively long-term harvest trends for specific management units and for individual states (Kluender et al., 1988; Kammermeyer, 1991; Wilson and McMaster, 1973); however, there have been no region-wide comparisons or analyses of harvest trends in the southerncal region of the United States. Given the importance and success of white-tailed deer populations in the south as a whole, it is desirable to have knowledge of harvest trends not only on a local level, but also on a regional level in order to facilitate evolving management strategies. The objectives of this study were to compare annual white-tailed deer harvest data from seven southerncal-central states and to determine significant trends in yearly harvest.

METHODS

A letter was sent to state deer biologists in each of seven southerncal states (Tennessee, Mississippi, Louisiana, Arkansas, Missouri, Oklahoma and Texas) requesting yearly deer harvest information. Each state responded, although the data available by state varied considerably. Some states were able to provide only total harvest for limited periods of time, while other states were able to provide fairly complete information for harvest by sex for long periods. Because of the variation in data collection formats, Texas and Louisiana could not be included in all of the analyses. For those states with more complete data sets, yearly harvest rates of antlered and antlerless deer (including does and button bucks) were entered separately. Antlerless deer percent of total harvest rate was calculated by year for each state.

A second data set consisted of cross sectional data gleaned from the Appendix of the Proceedings of the 1991 Annual Southeast Deer Study Group meeting. The study year was 1989. These data included variables by state for estimated herd size, total habitat area, total harvest, antlered harvest, antlerless deer harvest, hunting season length and number of hunters. Calculated variables included acres per deer, kill percent of total population, antlered deer percent of total harvest, antlerless deer percent of total harvest, acres per harvested deer, acres per hunter and harvest per hunter. Statistics were compared across states for trends and to determine what factors were consistently associated with high total harvest rates. Data entry and analysis were accomplished with Quattro (Borland, 1991), a spread sheet, and Systat (Wilkinson, 1990), a statistics package.

The time series data were handled in a fundamentally different manner than the cross-sectional data. Data were first plotted over time to determine long-term harvest trends by total and sex group by state; general trends were noted. Next, yearly total harvest, antlered harvest and antlerless deer harvest rates were first differentiated to remove long-term trends from the data and to eliminate first order auto-correlation. First differencing is an effective tool in revealing cyclic variability in a time series.

The need for first differencing is recognized by inspection of the auto-correlation coefficients and the partial auto-correlation coefficients of a time series (Hoff, 1983). A fundamental assumption of time series analysis is that an observation of a variable in time T is a function of its value in time T-1 plus an error term, e, that contains current period influences. This relationship is generally expressed in Equation 1.

\[ Y_T = f(Y_{T-1} + e_T) \]

(1)

In order to isolate current period information free of past period information, the series is first differentiated to leave the pure error series, e_T, as in Equation 2.

\[ e_T = f(Y_{T-1} - Y_{T-2}) \]

(2)

This transformation leaves all of the current period information in the data while removing influences of prior time periods. Note that the information contained in this series is the change in the value of a series from one time period to another. It is similar to the periodic growth rate of the series.

RESULTS AND DISCUSSION

CROSS-SECTIONAL DATA:

Deer habitat by state ranged from nine million (OK) to 71.7 million acres (TX) (Table 1). Average habitat was 17.5 million acres per state without Texas included and 39.4 million acres with Texas. Estimated deer populations ranged from a low of 250,000 (OK) to a maximum of 3,500,000 (TX); average estimated population (without TX) was 780,000...
Table 1. Southcentral states white-tailed deer harvest statistics for 1989.

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>AR</th>
<th>LA</th>
<th>MO</th>
<th>MS</th>
<th>OK</th>
<th>TN</th>
<th>TX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Habitat (M ac.)</td>
<td>28,594</td>
<td>17,000</td>
<td>13,694</td>
<td>20,000</td>
<td>8,949</td>
<td>14,492</td>
<td>71,600</td>
</tr>
<tr>
<td>Herd size (M)</td>
<td>700,000</td>
<td>450,000</td>
<td>720,000</td>
<td>1,700,000</td>
<td>250,000</td>
<td>625,000</td>
<td>3,200,000</td>
</tr>
<tr>
<td>Area per deer (ac.)</td>
<td>40.6</td>
<td>26.2</td>
<td>18.3</td>
<td>11.8</td>
<td>35.8</td>
<td>26.4</td>
<td>20.3</td>
</tr>
<tr>
<td>Total Harvest</td>
<td>113,879</td>
<td>170,000</td>
<td>137,153</td>
<td>282,266</td>
<td>38,341</td>
<td>106,782</td>
<td>477,491</td>
</tr>
<tr>
<td>Deer Harvest</td>
<td>34,243</td>
<td>48,000</td>
<td>62,246</td>
<td>72,854</td>
<td>8,515</td>
<td>33,124</td>
<td>221,446</td>
</tr>
<tr>
<td>Percent of population harvested (%)</td>
<td>16.15</td>
<td>26.15</td>
<td>28.95</td>
<td>15.44</td>
<td>15.23</td>
<td>17.49</td>
<td>13.64</td>
</tr>
<tr>
<td>Hunter density (per hunter)</td>
<td>NA</td>
<td>84.99</td>
<td>34.23</td>
<td>100.00</td>
<td>83.12</td>
<td>83.44</td>
<td>127.10</td>
</tr>
<tr>
<td>Hunter success ratio (deer/hunter)</td>
<td>NA</td>
<td>0.85</td>
<td>0.39</td>
<td>1.31</td>
<td>0.18</td>
<td>0.55</td>
<td>0.84</td>
</tr>
</tbody>
</table>

animals. Average acres per deer was estimated at 25.7 with a high of 40.9 acres per deer and a low of 11.8 acres per deer. Total harvest ranged from a high of 478,000 in TX to a low of 38,350 in OK. Average harvest amounted to 17.9% of the herd, with a high of 26.2% (LA) and a low of 13.6% (TX). Antlerless deer percent of total harvest ranged from a low of 22.2% (OK) to a high of 46.4% (TX). Hunting density was highest in MO with 34 acres per hunter and lowest in Texas with 127 acres per hunter (based on total deer habitat). Average success rates (total harvest / total number of hunters) varied from a low of 20% in OK to a high of 131% in MS where hunters averaged more than one deer each.

There was a strong correlation between total harvest and total habitat (r=.889), total herd size (r=.983), the number of hunters (r=.721) and hunter density per square mile (r=.732). Total harvest was also strongly related to the total number of antlerless deer harvested (r=974) and the percent of total harvest represented by antlerless deer (r=.763).

TIME SERIES DATA:

Generally, harvest increased over time in all southcentral states (Figures 1 and 2). The strongest increases in annual deer harvest took place after 1977 or 1978; however, some states, such as Tennessee and Arkansas, did not begin to significantly increase harvest until the early 1980s. All states that are characterized by significant increases in total deer harvest have had at least 20% of their total harvest in the antlerless class. Moreover, states that have consistently harvested more than 100,000 deer annually since 1977 have had at least 30% of the total harvest in the antlerless class. Antlerless deer percentages of 35-40% are more prevalent in the states with annual harvests over 150,000. Since 1988, antlerless deer have accounted for over 50% of Missouri’s harvest of deer. Other states (MS and TX) are not far behind this level.

The trend to increase the numbers of harvested antlerless deer is a sharp departure from deep rooted conventional wisdom. The move to increase doe harvest has been at the instigation of deer biologists who recognize that, with growing herd sizes, antlerless deer must be harvested at an increasing level to insure herd health as herds approach carrying capacity. Doe harvest is also critical to maintaining herds at acceptable levels to minimize the problems at the deer-human interface such as crop depredation and deer-vehicle collisions (Wigley et al, 1990).

The first differenced time series for total harvest and antlered harvest for most states showed strong cyclical patterns (e.g. Oklahoma, Figure 3). Usually the pattern repeated on a four year cycle, although one series varied on a three year cycle. Cycles were roughly coincident for all of the states, but only three (AR, TN, and OK) are depicted in Figure 4 for clarity. The same cyclic pattern was present in the antlered as well as the antlerless portion of the harvest; however, the pattern in the antlerless deer harvest is not as clear. Note also that the amplitude of the cyclic pattern has increased over time. This increasing variance is at least somewhat attributable to the total harvest level over time.
A major question arises about the meaning and cause of the cyclic nature of the first differenced state harvest series. Two general hypotheses arise: first, that the cycle is human induced. At least two possibilities exist in this category. One is that the cycle is a result of the quasi-political process of setting season lengths, i.e., biologists and commissioners operating in concert across state lines or regionally purposefully "hit the herd hard" every two, three or four years. However, state differences in management objectives mitigate against this reasoning. Another is that the cycle is a result of fluctuations in hunting effort region wide. This hypothesis is weak, however, because over-all harvest levels have typically risen consistently for long periods while the number of hunters in many states have actually decreased somewhat since 1980 (Kluender et al., 1988).

The second major hypothesis is that the cycle is a biological phenomena, and that the observed cycle represents the removal of the harvestable portion of a regularly eruptive biological population. A high linear correlation (r=0.983) between total harvest and population suggests the hypothesis that harvest represents a relatively fixed proportion of the total population, regardless of population size. Recall that the average harvest percent of total population for the southcentral states is 17.9% (sd=4.3). Since yearly harvest is a function of the population and the proportional harvest by state is relatively consistent over time regardless of population size, then harvest numbers probably reflect the underlying population of active, healthy deer during hunting seasons. Accepting the proposition that we are dealing with a cycling biological phenomena, the question arises as to the cause of the observed cycles. Note that these cycles appear to be more reminiscent of the short cycles characteristic of many small mammal populations (relatively r-selected species) than of the relatively longer cycles observed in a few larger mammals (relatively K-selected species) (Plaunke 1970).

Possibilities for the apparent population cycle include regional weather patterns which include rain fall that produces cycles in mast and forage production and hence recruitment and fawn survival. A second possibility is the cyclic eruptive nature of epizootic hemorrhagic disease (HD) in the southern United States. Figure 5 shows the incidence level of HD by year with the number of southern counties affected by the disease. When first differenced data for HD cycles is plotted with first differenced data of total harvest in most of the southern states a strong negative correlation between the disease and harvest change is noted. Tennessee is used here as an example (Figure 6). Note that when HD incidence is on the upswing (i.e., peak years for disease outbreak, harvest is lowered significantly). In years when HD is at low levels we note a significant increase in harvest levels.

While HD outbreaks do not prove causality of lowered harvest levels, the strong negative correlation between the events does strongly suggest a relationship. If we accept that the reduction in harvests on a cyclical basis may be caused by HD, then it appears that the disease might be much more virulent and devastating than had been previously suspected. Sudden drops in harvest levels of up to 10,000 harvested animals mark the first differenced harvest data of many states (e.g., TN, AR, MS). If this drop is equivalent to the average portion (17.8%) of the herd that is harvested, the total drop in active, healthy, deer during fall hunting season due to HD may be as high as 60,000 deer in a single state. This is equivalent to over one third the yearly legal harvest per year in many southcentral states.

If late summer, pre-hunting season HD epidemics are eliminating this many deer from potential harvest in peak years, managers will find it exceedingly hard to wisely structure hunting regulations. This is compounded by the fact that season dates are customarily set far in advance of actual seasons. Clearly, more research is needed to confirm the degree and extent of HD influence on deer harvest.
SUMMARY

White-tailed deer herd sizes across the southcentral states have been increasing since the 1960s. Concurrent with this increase has come a total harvest level increase for most southcentral states. This trend has been especially strong since 1980. Southcentral states have increased bag limits on antlerless deer to insure that herd health is maintained as herd sizes approach total carrying capacity. In states with large yearly harvests antlerless deer tend to account for 40% or more of the total harvest. Increasing doe harvest, however, is difficult for many traditionally bucks-only hunters to accept.

Harvest growth rates show irregularities from year to year. The cyclic pattern of harvest (and population) growth rate is of shorter duration than would be expected in a large ungulate population and is closer to that exhibited by more r-controlled populations. Observed cyclic patterns in harvest growth rates move opposite the growth rate of epizootic hemorrhagic disease incidence in southcentral US counties. Initial research suggests a strong link between HD disease incidence and harvest growth rate changes. As herds continue to grow and approach carrying capacity on many southern sites, management challenges will increase.

LITERATURE CITED


PHYTOPLANKTON COMMUNITY
ABUNDANCE AND DIVERSITY IN
DARDANELLLE RESERVOIR, ARKANSAS, 1981-1990

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ABSTRACT

Phytoplankton samples were collected quarterly from 1981-1990 at five stations representing discharge water from Arkansas Nuclear One, a nuclear generating station, and four "control" or "dispersal evaluation" stations. Seventy-five taxa representing five divisions were identified and enumerated. Community structure was evaluated using abundances, number of taxa, and Margalef's Richness, Shannon's Heterogeneity and Pielou's Evenness indices. No long-term trends were identified, but the beginning of cyclic variations, with a 7-year periodicity, in abundance, number of taxa, and Shannon's and Pielou's indices were apparent. Margalef's index values were constant during most of the study period. For all samples, t-tests and Mann-Whitney U tests between station 5 (discharge) and each of four "control" stations, revealed no significant differences with any variable.

INTRODUCTION

In the late 1960s Arkansas Power and Light Company began construction on a two-unit nuclear generating facility located on the north shoreline of Dardanellle Reservoir. Environmental studies were initiated at that time and have continued until the present. The principal objective of these studies has been to determine the environmental compatibility of the construction and operation of the generating station. Secondary objectives have included, but not been limited to, describing resident taxa, population dynamics, diversity and community structure of benthos, phytoplankton and zooplankton. Rickett and Watson (1983) reported on the phytoplankton community dynamics during the first time-segment (1975-1982) following the beginning of commercial operation of Unit I, which uses reservoir water once through for condenser cooling. The earlier report emphasized taxon-specific abundance variations and community dominance. Phytoplankton diversity and abundance did not reveal similar trends but included strong temporal variations. Another secondary objective was the use of specific features of the phytoplankton community as a back-up indicator of general water quality. That algal species assemblages may be used as indicators of general water quality and of fluctuations in the concentrations of selected metal ions was determined by Meyer (1971) and Rice and Meyer (1977), respectively.

This report presents additional data (since 1983) and emphasizes a more detailed analysis of diversity in addition to taxa and abundances.

SITE DESCRIPTION

Dardanellle Reservoir was created on the main channel of the Arkansas River by the Kerr-McClellan Navigation System in the early 1960s and is managed by the U.S. Army Corps of Engineers. Rickett and Watson (1985) reported morphometric data on the reservoir and a general description of watershed components. Since 1985, additional housing and urban development have occurred north and west of the city of Russellville, and limited development of agriculture and silviculture has occurred elsewhere in the watershed. There have also been minor development projects such as roads, small businesses and individual housing units in the watershed area.

Five stations were established to sample all major reservoir microhabitats (Figure 1). The intake and upstream control stations (16 and 21, respectively) were distanced beyond the influence of the thermal effluent (discharge, station 5), whereas the mid-lake station (11) was expected to be within its influence. Further downstream in the reservoir, no residual effects of discharge were expected, and station 15 was established to test this.

METHODS

Depth-integrated phytoplankton samples were collected quarterly at five stations on the reservoir during the years 1981-1990. Two hundred liters of water were pumped through a Wisconsin-style plankton net having 80-micron mesh size, and the filtrate was preserved with Meyer's fixative. Approximately two-thirds of the volume was taken from the surface to 0.3 m depth, whereas the remaining third was taken equally from 0.3 to 3.0 m, which generally represented the depth of the euphotic zone. In the lab, sample aliquots were placed in a Sedgwick-Rafter counting cell and viewed at 100x with a Nikon inverted microscope equipped with a mechanical stage. Cells were identified to genus and tabulated as cells per liter.

Abundances per season at station 5 were compared with those at each of the four "control" stations. Data pairs with non-significant (α = 0.05)
F-tests were further compared with t-tests, whereas those with significant F-tests (too much heterogeneity for t-tests) were compared with Mann-Whitney U tests. Three indices were used to describe community diversity: Margalef’s Richness, Shannon’s Heterogeneity and Pielou’s Evenness. The Margalef formula considers the number of taxa in a sample and the total number of organisms comprising those taxa. The Shannon index evaluates how the individuals are distributed among the taxa, whereas the Pielou Evenness index is somewhat more sensitive than Shannon’s in that it relates that distribution back to the number of taxa in the sample. Formulas and notations are given in the Appendix. For all indices used, an increase in the number of taxa or a decrease in the number of individuals or individuals per taxon may produce a larger calculated value, a feature which must be considered for interpretation.

RESULTS AND DISCUSSION

Seventy-five genera in five divisions were identified (Table 1). Chlorophyta exhibited the most extensive adaptive radiation with the greatest variety of taxa (34), followed by Chrysophyta (23) and Cryptophyta (21). Euglenophyta and Pryrophyta were represented by two taxa each. Chrysophyta life cycles were most stable and consistent, showing numerical dominance in all seasons with the peak of abundance in summer (Figure 2). The abundance peak for Cyanophyta also occurred in the summer when water temperatures were highest and overall river discharge was usually lowest. The peak of abundance for Chlorophyta occurred in fall (Figure 2). Rickert and Watson (1983) reported 30 taxa of Chlorophyta, 20 of Cryptophyta, 11 of Cyanophyta, and two each of Euglenophyta and Pryrophyta. Seasonal abundance and diversity of the period 1975-80 were similar to those observed during this study.

Table 1. Taxonomy of Phytoplankton in Dardanelle Reservoir, 1981-1990.

<table>
<thead>
<tr>
<th>Cyanophyta</th>
<th>26. Pleurodexia</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Anabaena</td>
<td>27. Scenedesmus</td>
</tr>
<tr>
<td>2. Anabenaepis</td>
<td>28. Schroederia</td>
</tr>
<tr>
<td>3. Anoaxepsonmon</td>
<td>29. Sphaerocystis</td>
</tr>
<tr>
<td>4. Arithrospira</td>
<td>30. Spiropyra</td>
</tr>
<tr>
<td>5. Boria</td>
<td>31. Staurostrum</td>
</tr>
<tr>
<td>6. Chroococcus</td>
<td>32. Ulothrix</td>
</tr>
<tr>
<td>7. Closteriopsis</td>
<td>33. Volvox</td>
</tr>
<tr>
<td>8. Cryptocapsa</td>
<td>34. Zygnema</td>
</tr>
<tr>
<td>9. Lyngbya</td>
<td>35. Euglenopedia</td>
</tr>
<tr>
<td>10. Microcystis</td>
<td>36. Eulonephrya</td>
</tr>
<tr>
<td>11. Oscillatoria</td>
<td>37. Euriglena</td>
</tr>
<tr>
<td>12. Scytomena</td>
<td>38. Phacus</td>
</tr>
<tr>
<td>14. Trichodesmis</td>
<td>40. Pyrrophyta</td>
</tr>
<tr>
<td>Chlorophyta</td>
<td>1. Ceratium</td>
</tr>
<tr>
<td>1. Actinastrium</td>
<td>2. Peridinium</td>
</tr>
<tr>
<td>2. Anthothecus</td>
<td>Chrysophyta</td>
</tr>
<tr>
<td>3. Bambusina</td>
<td></td>
</tr>
<tr>
<td>4. Cerasterias</td>
<td>1. Asterionella</td>
</tr>
<tr>
<td>5. Cleasteriopsis</td>
<td>2. Bacillaria</td>
</tr>
<tr>
<td>6. Closteria</td>
<td>3. Centronella</td>
</tr>
<tr>
<td>7. Chlorcola</td>
<td>4. Cyclotella</td>
</tr>
<tr>
<td>8. Closterella</td>
<td>5. Cyphella</td>
</tr>
<tr>
<td>9. Closterella</td>
<td>6. Diatomella</td>
</tr>
<tr>
<td>10. Cosmarium</td>
<td>7. Dinobryon</td>
</tr>
<tr>
<td>11. Dictyospherium</td>
<td>8. Elippospinid</td>
</tr>
<tr>
<td>15. Eutetramorius</td>
<td>12. Meridion</td>
</tr>
<tr>
<td>18. Kirchnerella</td>
<td>15. Nitzschia</td>
</tr>
<tr>
<td>20. Monorota</td>
<td>17. Staurospira</td>
</tr>
<tr>
<td>22. Pandorina</td>
<td>19. Sullella</td>
</tr>
<tr>
<td>23. Pediasastrum</td>
<td>20. Synedra</td>
</tr>
<tr>
<td>25. Plidorsina</td>
<td>22. Tabellaria</td>
</tr>
<tr>
<td>26. Pterionella</td>
<td>23. Tribonema</td>
</tr>
</tbody>
</table>

There was a strong overall abundance peak about mid-year for all years except 1985, 1987, 1988 and 1989. These peaks were commonly five to 10 times greater than the trough on either side of the peak. Figure 2. Station 21 exhibited the highest peaks. Peaks of abundance at station 5 declined more-or-less steadily from about 20,000 in 1981 to less than 5,000 in 1990, while peaks at station 16 rose more-or-less steadily from about 11,500 in 1981 to nearly 18,000 in 1988 and dropped sharply off to 3,500 in 1990. River discharge (Q) variations from 1978 through 1990 are given in Figure 3. (U.S.G.S. 1978-90). Relatively low flows from 1978 to 1982 could, on the basis of nutrient depletion, explain the depressed phytoplankton counts prior to 1983 (Figure 4), but otherwise, a correlation between discharge and abundance was not present.

Figure 2. Seasonal abundances of phytoplankton groups in Dardanelle Reservoir, 1981-1990.

Figure 3. Annual means of phytoplankton abundance (organisms/liter) in Dardanelle Reservoir, 1981-1990.
When "control" stations were plotted one at a time with station 5, most peaks of abundance coincided (Figure 5). T-tests and Mann-Whitney U tests did not reveal any significant differences of abundance, which indicated thermal effluent had no depressing effect on phytoplankton abundance. The number of phytoplankton taxa varied considerably among the quarterly samplers, but annual means revealed slight evidence of a seven-year periodicity with low points in 1981 and 1987, a high point in 1984 and possibly headed for another high point in 1991 or 1992 (Figure 6). Rickett and Watson (1983) reported very similar abundances between station 5 and each of the four "control" stations.

Shannon’s Heterogeneity index values exhibited a maximum in 1982-83 then declined and leveled off for the rest of this reporting period. When “control” stations were paired with station 5 and plotted (Figure 8), most of the peaks and troughs coincided. T-tests did not reveal any significant differences. Pielou’s Evenness index values also exhibited maximum values in 1982-83, declining later and then leveling off. Plots of paired stations showed many coincidental peaks and troughs (Figure 9), and t-tests revealed no significant differences.
Phytoplankton Community Abundance and Diversity In Dardanelle Reservoir, Arkansas, 1981-1990

Cyanophyta and Chrysophyta were more abundant in summer and Chlorophyta were slightly more abundant in the fall than any other season. Chrysophyta was the most abundant group in all seasons, and they along with Cyanophyta and Chlorophyta comprised approximately 98 percent of all organisms.

Station 5, when compared with other stations, exhibited no significant differences with respect to any of the variables considered. Thermal discharge did not significantly alter abundance or the indices used to evaluate community diversity.

ACKNOWLEDGMENT

The authors thank Arkansas Power and Light Company/Entergy Corporation for financial support of this project.

REFERENCES CITED


APPENDIX

Margalef's (MRI) = \( S - 1 \) \( \log N \), where S and N are the numbers of taxa and individuals, respectively.

Shannon's (SHI) = \( \sum (p_j) \log_{10} (p_j) \), where \( p_j \) is the proportion of the entire sample comprised by the ith taxon.

\[ \text{Pielou' (PEI)} = \frac{\text{SHI}}{\log_{10} N} \]

SUMMARY

Although considerable season-by-season variation existed for all tested variables, no long-term trends were identified. Annual means of abundances, numbers of taxa, and Shannon's Heterogeneity and Pielou's Evenness indices indicated the possible beginning of a cyclic oscillation with a 7-year periodicity. Margalef's Richness index was constant during the last eight years of the study period. Low abundances during 1981-1983 were probably related to a 4-year period of relatively low river discharge (1978-1982).
ZOOPLANKTON ABUNDANCE AND DIVERSITY IN DARDANELLE RESERVOIR, ARKANSAS, 1981-1990

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ABSTRACT

Zooplankton samples were collected quarterly from five stations representing the discharge bay and four "control" or "dispersing impact" stations. Rotifers dominated all samples numerically and by the number of taxa. All major groups (Rotifera, Cladocera, Copepoda, and Protozoa) exhibited greatest abundance during the summer. Quarterly variations in abundance and number of taxa were documented. Except for an increase in taxonomic analysis detail between 1981 and 1984 resulting in several more taxa added to the list, no long-term increases, declines or repeating cycles were apparent. Margalef's Richness Index reflected this change and showed a long-term increase with evidence of a 5- to 6-year repeating cycle. Shannon's Heterogeneity and Pielou's Evenness Indices showed no obvious trend or cycle. When these variables at Sta. 5 (discharge) were compared with other stations, no significant differences (α = 0.05) were documented.

INTRODUCTION

Environmental studies on Dardanelle Reservoir have included plankton surveys (Palko 1970; Rickett and Watson 1983a, 1983b), surveys of radioisotopes and general water chemistry (Rickett and Watson 1985). Several of these studies, including the present one, have been funded by Arkansas Power & Light Company (presently Entergy Corporation) to determine the environmental compatibility of the operation of Arkansas Nuclear One, a generating facility located on the north shore of the reservoir. Unit I of this facility began commercial production in 1975 and uses reservoir water pumped once through for condenser cooling. Rickett and Watson (1983a) described the general structure of the zooplankton community (taxa, abundances and temporal variations) between 1975 and 1983.

The principal objective of this project segment has been to document longer-term impacts, if any, of plant operation on the composition and variations in the zooplankton community for the period 1981 through 1990. A secondary objective of this report was to review river discharge variations and relate such variations, if possible, to variations in the zooplankton community.

SITE DESCRIPTION

Dardanelle Reservoir was created on the main channel of the Arkansas River by the Kerr-McClellan Navigation System in the early 1960s and has been managed by the U.S. Army Corps of Engineers. Rickett and Watson (1985) reported morphometric data on the reservoir and a general description of watershed components. Since 1985 additional housing and urban development have occurred north and west of the city of Russellville, and limited development of agriculture and silviculture has occurred elsewhere in the watershed. There have also been minor development projects such as roads, small businesses and individual housing units in the watershed area.

Five stations were established to sample different general areas of the reservoir as well as to compare four "control" stations with the discharge station (Figure 1). The intake and upstream control stations (16 and 21, respectively) were distanced beyond the influence of the thermal discharge (5), whereas the mid-lake station (11) was expected to be within its influence. By the time discharge water reached the downstream station (15), no residual heat was expected to remain.

METHODS

Depth-integrated zooplankton samples were collected quarterly at five stations on the reservoir during the years 1981-1990. Two hundred liters of water were pumped through a Wisconsin-style plankton net having 80-micron mesh size, and the filtrate was preserved with Meyer's fixative. Approximately two-thirds of the volume was taken from the surface to 0.3 m depth, whereas the remaining third was taken equally from 0.3 to 3.0 m, a depth generally representing the lower margin of the euphotic zone. In the lab, sample aliquots were placed in a Sedgewick-Rafter counting cell and viewed at 100X with a Nikon inverted microscope equipped with a mechanical stage. Organisms were identified to genus and tabulated as number per liter.

Community structure was described by evaluating zooplankton abundances, number of taxa, and three indices of diversity: Margalef's Richness, Shannon's Heterogeneity and Pielou's Evenness (see Appendix for formulae and notations). The Margalef formula compares the number...
of taxa in a sample and the total number of organisms comprising those taxa. The Shannon index evaluates how the individuals are distributed among the taxa, whereas the Pielou Evenness index is somewhat more sensitive than Shannon’s in that it relates the distribution if the individuals back to the number of taxa in the sample. For all indices used, an increase in number of taxa without changing the number of individuals, or a decrease in the number of individuals per taxon without changing the number of taxa produces a larger calculated value, a feature which must be considered for interpretation.

RESULTS AND DISCUSSION

Forty-one genera representing the Protozoa, Rotifers, Copepoda and Cladocera were identified and enumerated (Table 1). Unspecified genera of Nematoda, Tardigrada and Ostracoda were also occasionally encountered and recorded. Rotifers dominated the samples during all seasons of the year, comprising 79 to 91.5 percent of individuals (Figure 2) and demonstrating peaks of abundance in the summer. The other three major groups also exhibited their abundance peaks in the summer, but, combined, accounted for only 10-20 percent of the samples.

Table 1. List of zooplankton genera in Dardanelle Reservoir, 1981-1990.


For the mean number of organisms per station, the years 1981-1983 exhibited consistently low numbers (fewer than 1000 per liter), followed immediately (1984) by the highest peak of abundance of the project period. A second largest number was collected in 1987. In-between peaks occurred approximately once per year. Plotting annual means revealed a distinct bi-modal curve with modes at 1984 and 1987 and a steep decline from late 1987-1990 (Figure 3). However, the examination of abundance curves for the individual stations showed two distinct patterns. Stations 11, 15 and 21, all in the main body of the reservoir, still exhibited bi-modal curves, but station 16 (intake) showed a curve with a single mode in 1987. Station 5 (discharge) had an intermediate abundance curve with a small mode in 1984, showing the mixing effect as the discharge water met the main body of the reservoir. Water taken into the plant was drawn from the Illinois Bayou arm of the reservoir and contained a number of different characteristics (Ricketts and Watson 1985), reflected here by variations in zooplankton abundance.

When stations 11, 15, 16 and 21 were each paired with station 5 graphically, quarterly abundance peaks coincided in all pairs (Figure 4).
Differences in peak height, particularly in 1984 and 1987 were present, but t-tests showed no significant difference (t = 0.05) within any pair of abundance curves. The number of taxa identified rose sharply from a mean of seven (1981-1983) and ranged between 14 and 17.5 thereafter. This increase corresponded to an increase in the level of detail used in sample analysis (some taxon lumping had been done previously). The objective here, however, was to compare the number of taxa collected at station 5 with the other stations (Figure 5). No significant differences were observed when stations were paired, and no long-term trends were identified.

A composite of Margalef's Richness Index for all stations contained a peak which corresponded to the strongest abundance spike in 1985 (Figure 6). This peak was preceded by the lowest richness values for the study period, and a second peak of equal magnitude was in evidence in 1990. These curves corresponded generally to the number of taxa. When richness indices of Sta. 11, 15, 16 and 21 were compared with that of station 5, t-tests revealed no significant differences.

Shannon's Heterogeneity Index increased gradually during the study period with minor dips in 1984 and 1988 (Figure 7). Greatest community heterogeneity was observed between 1985-1987 and 1989-1990. When stations were graphically and statistically compared in the pattern as before, no significant differences were noted.

Individual organisms were more evenly distributed among the taxa early in the study period (Figure 8), but after 1984 Pielou's Evenness Index remained fairly constant. When station 5 was compared with others, t-tests revealed no significant differences.

Numerical fluctuations of zooplankton did not always coincide with the same for phytoplankton (Rickett and Watson, 1992). If we were to assume a number of close predator-prey relationships between phytoplankton species and zooplankton species, we would expect a larger number of phytoplankton to support a given number of zooplankton. Calculation of P/Z (phytoplankton/zooplankton) ratios was a quick way

Figure 5. Numbers of zooplankton taxa at the discharge station compared with each "control" station, Dardenelle Reservoir, 1981-1990.

Figure 6. Annual means of Margalef's Richness index for zooplankton, Dardenelle Reservoir, 1981-1990.

Figure 7. Annual means of Shannon's Heterogeneity index for zooplankton, Dardenelle Reservoir, 1981-1990.

Figure 8. Annual means of Pielou's evenness index for zooplankton, Dardenelle Reservoir, 1981-1990.
to assess this relationship (Figure 9). During 70 percent of the study period, P/Z ratios were around or less than 2, too low to agree with the usual ecological pyramid. The lowest P/Z ratios corresponded to a strong zooplankton abundance peak and phytoplankton abundance dip in 1987. Perhaps a close feeding relationship does not exist continually, and some of the zooplankton were feeding on larger suspended particulates or small mauplii or were preying on each other for a time. Cannibalization of mauplii might partly explain the sharp decline in their own numbers between 1987 and 1990.

![Figure 9. Phytoplankton/Zooplankton (P/Z) ratios based on numerical standing crop, Dardanelle Reservoir, 1981-1990.](image)

**SUMMARY**

Rotifers constituted 79 to 91.5 percent of the numerical standing crop. All major groups of zooplankton exhibited greatest abundances during the summer. Considerable quarterly variations in abundance were present with peaks occurring in 1984 and 1987. Similar variations in the number of taxa collected were also present with a slight peak developing in 1987. Neither long-term trends nor cyclic patterns were apparent. With the possible exception of Margalef's Richness, the diversity indices exhibited no long-term trends or cyclic patterns. Margalef's Richness definitely showed an increase over the 10 years. Part of the early increase (1981-1985) was due to increasing analysis detail. Other than Pielou's Evenness index exhibiting a mirror image of Margalef's during 1981-1984, the other indices did not show corresponding variation. Shannon's Heterogeneity exhibited a gentle but steady increase, whereas Pielou's Evenness remained constant after 1984. When all variables at station 5 were compared with all other stations, no significant differences were observed.

**ACKNOWLEDGMENT**

The authors thank Arkansas Power and Light Company/Entergy Corporation for financial support of this project.

**APPENDIX**

Margalef's Richness Index (MRI) = \( \frac{S - 1}{\log(N)} \), where \( S \) is the number of taxa; \( N \) is the total number of individuals.

Shannon's Heterogeneity Index (SHI) = \( \sum (p_i) \log(p_i) \), where \( p_i \) is the proportion the ith taxon comprises of the entire sample.

Pielou's Evenness Index (PEI) = \( \frac{\text{SHI}}{\log(S)} \).

**LITERATURE CITED**


REPRODUCTION IN THE WESTERN MUD SNAKE, 
FARANCIA ABACURA REINWARDTII  
(SERPENTES: COLUBRIDAE), IN ARKANSAS

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ABSTRACT

The reproductive cycle of Farancia abacura reinwardtii was studied using samples of snakes collected throughout Arkansas from 1985 to 1991; museum specimens were also examined. The right testes of 22 males was examined by light microscopy. Histological analysis of the testis indicated a postnuptial spermatogonogenic cycle. Testicular recrudescence begins in late May with sperm production peaking in late summer; sperm overwinter in the ductus deferens. Ovarian follicles of 22 females were measured and counted; two follicular sizes were noted. In those undergoing primary vitellogenesis, a maximum size of 6.5 mm was reached; those exhibiting secondary vitellogenesis ranged in size from 12 to 21 mm. Average clutch size in females with follicles over 10 mm was 14.6 (n=6). Oviductal eggs were observed in a single female in early September. Female F. abacura require at least 2.5 years to become sexually mature. Follicular growth is slow over the first two years but increases dramatically during the spring of the third year.

INTRODUCTION

The western mud snake, Farancia abacura reinwardtii, is a large-bodied, aquatic colubrid that ranges throughout much of the southeastern and southcentral United States (Conant and Collins, 1991). The mud snake inhabits shallow, soft-bottomed waterways with slow current, favoring cypress swamps, sloughs, bogs, creeks, and marshes. Amphibians and small mammals are the preferred food of adults, although freshwater eels, frogs, tadpoles, aquatic salamanders, and fish are preyed upon (Emst and Barbour, 1989).

The reproductive biology of F. a. reinwardtii has received very little attention (McDaniel and Karges, 1982; Mitchell, 1982); most accounts deal with morphological features, feeding habits, distribution, and habitat. The breeding season of this oviparous snake is not well understood with few and varying documented accounts of mating. Fitch (1983) stated that F. abacura is one of the most prolific North American snakes; however, clutch size records are few and not well distributed to show geographic variation. The Arkansas populations of F. a. reinwardtii occupy the northwesternmost extent of the range of the species; thus, data on the reproductive biology in Arkansas can contribute to a better evaluation of the variation in this wide-ranging species.

The present study was undertaken to document the reproductive biology of the species in Arkansas. We specifically investigated the timing of the testicular cycle as well as the type of ovarian cycle in females.

MATERIALS AND METHODS

Mud snakes were collected throughout Arkansas from 1985 to 1991 with additional individuals coming from preserved museum specimens (n = 44). Snakes were collected alive or dead on the road. Live snakes were given a lethal injection of sodium pentobarbital and fixed in 10% formalin. All snakes were sexed, and the SVL and tail length were recorded. Snakes were preserved in 70% ethanol and deposited in the Arkansas State University Museum of Zoology. The right testis and attached epididymis of 22 males were removed and prepared for light microscopy. Tissues were dehydrated in a graded series of ethanol and cleared in xylene. The testes were then embedded in paraffin, sectioned serially at 8 μm, and stained with Harris' hematoxylin and eosin. Each testis was examined by light microscopy noting testicular stage and presence of sperm in the ductus deferens. Seminiferous tubule diameters were measured using an ocular micrometer. The reproductive tracts of 22 females were examined macroscopically. The diameters of ova were measured to the nearest 0.1 mm with vernier calipers, and the number of variously-sized follicles was counted. Standard statistical data were obtained from all measurements; means are accompanied by ± 2 standard errors.

RESULTS

MALE TESTICULAR CYCLE

The left testis of the mud snake lies about one-third of the body length anterior to the vent. The testis is composed of a coiled mass of seminiferous tubules held together by a thin fibrous tunica albuginea. The interstitial spaces contain many interstitial cells, blood vessels, and some connective tissue cells. The seminiferous tubules contain numerous Sertoli (nurse) cells in variable amounts within a syncytium of germinal cells; germinal cell types fluctuate seasonally during the annual testicular cycle (Fox, 1952). The ducts deferentia, which consist of tall-to-flat epithelial cells, function in overwinter storage of spermatozoa. Spermatozoa in the ductus deferens were present in large quantities upon emergence from hibernation in the early spring, whereas the testes were completely regressed.

Seminiferous tubules exhibited mainly Sertoli cells and spermatogonia in April. Lumina of seminiferous tubules were occluded by the spermatogonia/Sertoli cell syncytium and large amounts of lipid droplets (Fig. 1). The ductus deferens were completely packed with sperm at this time (Fig. 1). This condition remained throughout April. Spermatogenesis began in May (Fig. 2). The seminiferous tubules exhibited primary spermatocytes as the dominant cell type. By mid-May one individual had a few secondary spermatocytes, and another individual had started producing secondary spermatocytes by the end of May. While the ductus deferens remained packed with sperm, the amount of lipid material within the tubules gradually disappears. In June secondary spermatocytes were the dominant cell type within the lumina of the seminiferous tubules (Fig. 2). Lipid droplets had become very scarce, and the ductus deferens, which had been packed with sperm until this time, had few or no sperm present. Only one individual was examined for the month of July. It possessed transforming spermatids, no lipid droplets, and scattered cellular debris in the ductus deferens (but no sperm). For the month of August there again was only one individual. In this male, mature sperm were present within
Testicular regression is assumed to be completed in the fall. The diameter of 30 mostly-circular seminiferous tubules per testis were measured. Each individual was categorized according to the cell type at the luminal margin. The mean tubule diameter with spermatogonia as the dominant cell type was 0.112 mm ± 0.01 (0.101 - 0.142). In tubules with primary spermatocytes as the dominant cell type we found a mean diameter of 0.125 mm ± 0.02 (0.086 - 0.197). Tubules with secondary spermatocytes present had a mean diameter of 0.116 mm ± 0.01 (.100 - 0.143). One individual with transforming spermatids present had a tubule diameter of 0.111 mm. The one individual with mature sperm present exhibited a tubule diameter of 0.173 mm. No obvious difference was observed between tubule diameters during the progressive stages of spermatogenesis.

**FEMALE OVARIAN CYCLE**

There are four basic size groups of ova in female *F. a. reinwardtii*. The first, group I, included follicles less than one mm in diameter (and were not counted or measured). Group II ova had a mean diameter of 4.19 mm ± 0.30 (range, 1.52 - 6.12). Group III ova had a mean diameter of 16.57 mm ± 1.32 (12.90 - 20.58). One female contained oviductal eggs, or group IV ova. We observed that older females (those with a greater SVL) underwent secondary vitellogenesis earlier in the year (Figs. 3 and 4) than less mature individuals (those with a smaller SVL).
We also observed individuals with enlarged follicles from mid-May to mid-July with one individual with oviducal eggs in early September (Fig. 3).

Mean clutch size using ova greater than 8 mm (group III ova) was 14.67 ± 1.94 (range, 8 - 20). This is approximately half the average number of group II ova present in each female. The mean clutch size of ova under 8 mm (group II ova) was 33.5 ± 3.44 (21 - 59).

DISCUSSION

Because of our lack of specimens during certain times of the year (i.e., late summer and autumn), we were unable to fully document the complete reproductive cycle. To better understand what course of events the testicular cycle of F. a. reinwardtii undergoes, we relied on the literature of previously described snake reproductive cycles. Our study indicated the following: 1) the testes are completely regressed upon emergence from hibernation in April with the ducts deferens packed with sperm, 2) primary spermatocytes are produced during May and secondary spermatocytes appear by early June with few to no sperm in the ductus deferens, 3) in July transforming spermatids were observed, and 4) by early August the testes had mature sperm present in the lumen and showed early signs of regression. With this in mind, the known part of the testicular cycle of F. a. reinwardtii closely parallels that of a number of other snakes. The ringneck snake, Diadophis punctatus, begins its annual testicular cycle in March which is earlier than that of Farancia; this regression begins in late spring (Myers, 1965). This same pattern was observed in the prairie rattlesnake, Crotalus viridis, (Aldridge, 1979a). The striped racer, Masticophis lateralis, has a testicular cycle in which regression (proliferation of spermatogonia) begins later than that of Farancia; i.e., regression begins in late June with spermatogenesis ending before hibernation and sperm overwintering in the ductus deferens (Goldberg, 1975). Both the whipsnake, Masticophis taeniatus, and the bullsnake, Pituophis catenifer (syn. P. melanoleucus), have testicular cycles that also closely resemble that of F. a. reinwardtii. There is an early summer recrudescence and late summer and autumn regression with sperm overwintering in the ductus deferens (Goldberg and Parker, 1975); other similar colubrid snakes include the corn snake, Carphophis vermiculatus (Aldridge and Metier, 1973); the Pacific Coast garter snake, Thamnophis elegans (Fox, 1952); and the glossy snake, Arizona elegans (Aldridge, 1979a). The cottonmouth, Agkistrodon piscivorus, (a viper) also has this same cycle (Johnson et al., 1982). A reproductive cycle of the esvital type is very common among the Colubridae and is probably the most prevalent kind in temperate regions (Saint Girons, 1982). Farancia does not fit the pattern of the coral snake, Micrurus fulvius. In this species regression begins in early summer, but spermatogenesis is interrupted by hibernation causing sperm to mature in the early spring before copulation (Quinn, 1979). By using comparisons with these testicular cycles, F. a. reinwardtii probably undergoes peak spermatogenesis in mid-to-late summer and is followed by an autumn regression.

We observed that F. a. reinwardtii testes in their regressed state (upon emergence from hibernation) contained large numbers of lipid droplets in the lumen of the seminiferous tubules. These lipid droplets began to decrease in size and number as spermatogenesis proceeds. By June nearly all of the lipid material was depleted. This lipid cycle is inversely related to the spermatogenic cycle in that lipid concentration is highest during times of no spermatogenic activity, and in lowest concentration during maximum sperm production. This lipid cycle has also been observed in the checkered water snake, Natrix piscator (Silvestava and Thapilyal, 1965); the striped racer, Elaphe taeniura (Chu and Wang, 1974); and the cobras, Naja naja (Lofts, 1966). The lipid material in Naja naja starts to appear as soon as testicular regression begins. Lipids reach their maximum concentration (size and number of droplets) just before testicular recrudescence. The last of the lipid droplets are then sloughed during the maturation of spermatids into spermatozoa (Lofts, 1966). Chu and Wang (1974) and Lofts (1966) indicated that lipid depletion was an indication of androgen production and release.

In female F. a. reinwardtii we observed the four basic size groups of ova. Betz (1963) provided a description of these size groups that he observed in the diamondbacked water snake, Nerodia rhombifer. In N. rhombifer group I follicles measured 0.1 mm in diameter (as we observed in F. a. reinwardtii). Betz (1963) also described group II follicles as ranging in size from 5 to 10 mm in Nerodia; we also observed a range of 1.52 - 6.12 mm in F. a. reinwardtii. Group III ranged from 10 - 20 mm in Nerodia and ranged from 12.90 - 20.58 mm in F. a. reinwardtii. At the end of a females first full year one would expect to find group I and II follicles present. At the end of the second year, group I, II, and III follicles are present. During the early summer of the third year (2.5 actual years), the group III follicles rapidly enlarge and become group IV, (i.e., oviducal eggs). Each year a new crop of group I follicles emerge from the germinal epithelium. The group I follicles from the previous year will then enlarge to become group II follicles and so on. Betz noted a decrease in the number of follicles each time follicles advanced to the next group. This was also observed in F. a. reinwardtii. He contributed this loss to atresia. There are approximately three times as many previtellogenic follicles as oviducal eggs in Nerodia sipedon (Aldridge, 1982).

Farancia a. reinwardtii falls into Aldridge's (1979b) type I ovarian cycle. In this cycle yolk deposition occurs in two stages. Primary vitellogenesis occurs in follicles of group I causing them to advance to group II. Secondary vitellogenesis occurs in group II causing them to advance to group III; in this stage they will mature in time to form oviducal eggs or group IV follicles. Type I ovarian cycles have been described in Arizona elegans, Diadophis punctatus, Pseudonaja nuchalis, Thamnophis proximus, T. radix, Nerodia sipedon, N. rhombifer, and Pseudechis porphyriacus (Aldridge, 1979b).

ACKNOWLEDGMENT

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LITERATURE CITED


DEVELOPMENT OF ORGANIC MUD MOUNDS IN A MIXED CARBONATE-SILICICLASTIC DEPOSITIONAL ENVIRONMENT

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ABSTRACT

Organic carbonate mud mounds in the Prairie Grove Member of the Hale Formation developed on a shallow shelf swept by competent tidal currents. The mounds were stabilized by crustose red algae and fostered a sheltered setting where phylloid algae and marine invertebrates could thrive. The mounds supplied skeletal sediment locally to the intermound areas as well as regionally along the stable platform. This sediment mixed with quartz sand to form a major mixed carbonate-siliciclastic system in northwestern Arkansas.

INTRODUCTION

Carbonate bioherms in Upper Mississippian and Lower Pennsylvanian strata of northwest Arkansas occupy stratigraphic positions between the more thoroughly investigated "Waulsortian reefs" of Early Mississippian age and the phylloid algal banks of Middle and Late Pennsylvanian age. Upper Mississippian mounds, localized in the Pitkin Formation, (Fig. 1) are features in which cyanobacteria and bryozoans trapped carbonate mud and silt (Webb, 1987). The Bloyd Formation (Fig. 1) of Early Pennsylvanian age contains mounds dominated by carbonate mud trapped and bound by stromatolites (Marsh, 1988). Both types grew in depositional settings where wave and current energy were not sufficiently competent to remove carbonate mud.

Carbonate bioherms, stratigraphically positioned at the base of the Prairie Grove Member of the Hale Formation (Fig. 1), are dominated by carbonate mudstone and a diverse group of marine algal and invertebrate components including abundant encrusting forms. They stabilized and developed in a depositional setting characterized by strong tidal currents and substantial sediment transport involving both skeletal grains and quartz sand. The growth of carbonate mud mounds in a high energy setting is unusual and differentiates these features from those stratigraphically below in the Pitkin Formation and above in the Bloyd Formation (Fig. 1).

LOCATION AND GEOMETRY

The carbonate bioherms in the Prairie Grove Member crop out in an elongate cut along Highway 23 approximately 11 miles south of Huntsville in Madison County, Arkansas (Fig. 2). The Highway trends north-south and the outcrop is located on the east side. Approximately 30 feet of Prairie Grove strata are continuously exposed over a distance of 780 feet. Two major and several smaller mounds and associated beds are present in this interval. Shale assigned to the underlying Cane Hill Member of the Hale Formation (Fig. 1) is exposed at highway level and the mounds stabilized and began development near the Cane Hill-Prairie Grove contact.
Major mounds in the interval range from 07 to 10 feet in thickness and 12 to 27 feet in breadth. Smaller satellite mounds are as small as two feet thick. The mounds are generally symmetrical (Fig. 3). They have well defined cretaceous areas and the flanks are inclined from 20 to 34 degrees away from the crests (Fig. 3). The mounds, within a solitary complex, are linked by tabular beds of mound lithology that extend from the base of a single mound to adjacent ones. Strata, laterally adjacent to the mounds, are characterized by current laminations and herringbone cross stratification. The mounds are massive and display little stratification. The boundaries between the mounds and the laminated flanking beds are both gradational and abrupt. The abrupt boundaries indicate that at the time they developed, the mounds had some synoptic relief and were clearly above the adjacent, current-swept sea floor. Transitional boundaries suggest that, at the time they developed, little relief was present and mound sediment mixed with sediment from the adjacent sea floor.

Figure 3. Outcrop of lower Prairie Grove strata along War Eagle Creek. Various facies and subfacies associated with the mounds are illustrated by (QA) calcareous quartzarenite, the mound facies which includes (HL) algal biolithite subfacies and (BM) skeletal biomicrite subfacies while (GS) represents the intermound grainstone facies. Cane Hill shale (CH) underlies the sequence.

LITHOFACIES

The mounds and the strata in which they are enveloped are lithically complex. The rocks involved have been assigned to the 1) calcareous quartzarenite, 2) skeletal grainstone, and 3) mound facies (Fig. 4). The mound facies contains two subfacies. Each facies and subfacies is believed to reflect a depositional environment extant when the mounds developed.

CALCAREOUS QUARTZARENITE FACIES

A shale unit at the top of the Cane Hill Member is directly overlain by laminated beds of the calcareous quartzarenite facies (Fig. 4). The facies is tabular in shape and ranges from 0.5 to one foot in thickness. It directly underlies each of the mounds (Figs. 3 & 4) and served as the substrate colonized by the mound organisms. Large bedforms created by currents may have formed bathymetric highs that were initially colonized by encrusting organisms. The calcareous quartzarenite facies is composed of fine to medium-grained quartz sandstone pervasively cemented by calcite.

Crinozoan and bryozoan skeletal fragments compose about 20% of the framework grains. The rock contains shale clasts derived from underlying Cane Hill strata.

MOUND FACIES

The mounds are composed of two major rock types assigned to the algal boundstone subfacies and the skeletal packstone subfacies. The boundstone subfacies contains abundant remains of encrusting organisms that stabilized carbonate mud. The associated skeletal packstone subfacies is composed of carbonate mud with abundant skeletal organisms and phylloid algae. Encrusting skeletal organisms in growth position are absent.

Algal Boundstone Subfacies

The algal boundstone subfacies is the central feature of all mounds and was the core around which the other environments developed (Fig. 4). The facies is composed of carbonate mud and contains abundant remains of crustose red algae. The encrusting coral *Aiolopora* is also present and grows within algal laminae (Fig. 5). Rugose corals and bryozoans occur in secondary amounts. Individual algal plants had plate-like morphologies and are most frequently preserved as laminae features composed of sparry calcite. In thin section, the algae appear as successive strips of sparry calcite (Fig. 6).

Rock of the algal boundstone subfacies is characterizedly affected by minor brecciation, due to bioturbation, suggesting that the mud had a degree of rigidity soon after deposition. This compactional affect created a rigid core which supplemented the ability of the crustose organisms to continue mound accretion within the strong winnowing regime of tidal currents. The algae-encrusted sediment-water interface and bound carbonates allowed vertical accretion and mound growth to occur. The algae-encrusted sediment also provided a substrate for rugose, occasional tabulate corals, and bryozoans to colonize and contribute to mound development (Figs. 5 & 6).

Skeletal Packstone Subfacies

The algal boundstone subfacies is bordered by mound strata assigned to the skeletal packstone facies (Fig. 4). This rock is composed of carbonate mud and skeletal grains of phylloid algae and bryozoans. The phylloid algae of the Prairie Grove mounds were probably green algae with aragonite skeletons. Modern forms characteristically inhabit environments protected from intense wave and current activity. The phylloid algae occur as plates of sparry calcite with no original microstructure preserved. The plants were erect and performed no binding function on passing sediment although they probably influenced mound growth by baffling carbonate mud thereby enhancing mound accretion. Bryozoans and occasional crinoidal fragments were transported to the environment from the adjacent boundstone lithosome. The protected setting was inhabited by fenestellid bryozoans, brachiopods, trilobites, foraminiferans, and numerous other invertebrates.

SKELETAL GRAINSTONE FACIES

The skeletal grainstone facies includes strata sedimented concurrently with the mound sediment as well as that which covered the mound.
interval (Fig. 4). These rocks are composed of crinoidal, bryozoan, and brachiopod grainstone. Quartz sand composes 20% to 40% of the framework grains (Fig. 7).

The beds are prominently laminated and display small-scale cross stratification (Fig. 8). They fill depressions and channel-ways in the mound complex as well as dominating the intermound areas. Laminations of quartz sand occur in the crests region of the mounds representing a transition from mound rock to the skeletal grainstone facies. This incursion of sand may have played a role in terminating mound growth.

DEPOSITIONAL SYNTHESIS

The Prairie Grove bioherms were established by the colonization of a firm substrate of calcareous sand (calcareous quartzarenite facies) by crustose red algae. The mounds developed as the binding activity of the algae consolidated carbonates muds and developed bathymetric relief (algal boundstone subfacies). Although erosional surfaces are present, the mounds were structurally resistant to competent tidal currents that swept the surrounding sea floor. The core of crustose red algae and mud provided a sheltered area on the leeward side of the individual mounds. Phylloid algae meadows flourished in these areas and contributed further

mud accumulation (skeletal packstone facies). Fenestral bryozoans, crinoids, brachiopods, trilobites and foraminifers also inhabited this environment and contributed to mound growth.

Skeletal and quartz sand of the skeletal grainstone facies was deposited adjacent to the mounds. These sands are frequently cross-bedded and always laminated. They are free of calcareous mud. The sedimentary structures and mud-free condition of the sand suggests that competent currents moved through the mound complex dominated by mud. This activity attests to the success of the crustose red algae in binding and retaining mud for mound construction in the face of strong currents.

The contact between mound lithologies and the adjacent skeletal grainstone facies is transitional in some areas and abrupt in others. Transitional facies suggest that the mound crests were only slightly above the adjacent sediment water interface and that mound growth was extremely slow and almost ceased. This is attributed to a greater supply of quartz sand and higher sedimentation rates that buried most of the mound. Small laminae of skeletal grainstone and quartz sand within the mounds indicate low relief allowing traction currents to transport sands across the mound surface.

Figure 8. Abrupt facies boundary between simultaneously deposited mound rock (MD) and intermound grainstone (GS). This contact infers vertical mound accretion rates greater than that of the coevally sedimented intermound sediment. Also note the laminated cross beds of the grainstone demonstrating competent currents which are required to laminate sand sized skeletal particles.
Abrupt boundaries (Fig. 8) are far more common and indicate that mound growth exceeded accumulation rates on the adjacent sea floor and that the relief exceeded two feet. During these times the supply of quartz sand was diminished and organisms could recolonize the mound surface. Quartz sand is far more abundant in strata that drape across the mound crests than in beds laterally adjacent to the mounds. This is reflected in the crestal areas of the mounds by alternating quartzose laminae and mound lithologies and suggests that ultimately a significant and prolonged increase in the supply of quartz sand may have buried the mounds and caused growth to cease.

The Prairie Grove Member of northwestern Arkansas is composed of quartz and skeletal sand and is characterized by horizontal laminations and cross stratification. The sediments accumulated on a high energy, shallow shelf dominated by strong tidal currents (Wiggins, 1978, Black, 1986). Quartz sand derived from the ancestral Mississippi River to the east was transported by competent north-south directed tidal currents across the shelf and impinged on the developing mounds (Fig 9). The mobile sand bottom was not suitable for widespread growth of marine invertebrates. The developing organic mounds provided the skeletal material that mixed with the quartz sand and was deposited locally around the mounds as well as transported regionally away from the mound complexes. These mounds existed as a skeletal sand factory supplying carbonate material for the Prairie Grove Member and formed a mixed carbonate/siliciclastic system in northwest Arkansas.

Figure 9. Early Morrowan paleogeographic map of Prairie Grove deposition with War Eagle Creek mound interval schematic depicting the development of the bioherms within the current systems which were actively transporting quartz and skeletal sand. VE = #4. (modified from Sutherland (1988) and Black (1986)).

LITERATURE CITED


4-SUBSTITUTED ANILIDES OF 2,6- AND 5,6-DICHLORONICOTINIC ACID. POTENTIAL AGRICULTURAL AGENTS.

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ABSTRACT

A series of 4-substituted anilides of 2,6- and 5,6-dichloronicotinic acid were prepared. The acids were first converted to their acid chlorides, which were in turn treated with the appropriate 4-substituted aniline in chloroform. A total of 16 anilides was thus prepared, and their structures confirmed. These compounds were prepared for testing as possible herbicidal, pesticidal or fungicidal agents.

INTRODUCTION

For over two decades, we have been engaged in the preparation of halogenated nicotinic acids and their derivatives, together with their subsequent evaluation as potential herbicidal, fungicidal and pesticidal agents (Setliff, 1970). Most recently we reported the preparation and characterization of a series of substituted anilides of 5-bromo-2-chloronicotinic acid and 5-bromo-6-chloronicotinic acid (Setliff and Caldwell, 1991), and were encouraged by the moderate activity demonstrated by several of these derivatives. The details of these evaluations, performed by the Research Division of a leading Agricultural Chemical Company, are confidential and cannot be reported here. Unfortunately, the activities of these compounds are organisim-specific, and further screening was not performed.

In view of the limited success of the bromochloro nicotanilides, it was decided to prepare a series of anilides of the isomeric 2,6- and 5,6-dichloronicotinic acids, in the hope that enriching the chlorine content might result in a more active and broader spectrum activity profile. We thus prepared the eight 4-substituted 2,6-dichloronicotanilides (Ia-h) and the eight 4-substituted 5,6-dichloronicotanilides (IIa-h), all of which are depicted in Figure 1.

MATERIALS AND METHODS

Melting points were determined on a Mel-Temp II apparatus and are uncorrected. Infrared spectra were taken on a Perkin Elmer 1430 recording instrument equipped with a Model 7300 data station and with samples prepared as KBr disks. 1H nmr spectra were determined in DMSO-d6 containing 1% TMS and were obtained on a Bruker 200 MHz FTAC-F superconductivity spectrometer equipped with ASPECT 300 computer control. Carbon, hydrogen, and nitrogen elemental analyses were done by Desert Analytics Organic Microanalysis, Inc., Tucson, Arizona.

Technical grade 2,6-dichloronicotinic acid (m.p. 141°-143°C) was obtained from Aldrich Chemical Company and was used without further purification. 5,6-Dichloronicotinic acid was prepared by oxidation of 5,6-dichloro-3-picoline (Setliff and Lane, 1976), and after recrystallization from water melted at 162-163°C.

The following general procedure was employed in the preparation of both the series I and II anilides. The dichloroacid (0.50 g; 0.0025 mol) and thiouyl chloride (3 ml) were combined and magnetically stirred under gentle reflux for 30 minutes, whereupon the acid dissolved. The reaction mixture was allowed to cool to room temperature, and the excess thiouyl chloride was removed under reduced pressure on a rotary evaporator. The residual acid chloride was taken up in dry chloroform (3 ml) and added to the appropriately substituted aniline (0.0038 mol) which had been dissolved in dry chloroform (10 ml). The resulting suspension was then stirred under reflux for 30 minutes. (Note: In case of the 4-nitroanilides Ii and IIb, dry benzene was used as solvent and the reflux time was extended to 1 hour). The reaction mixture was cooled, and the solid collected by vacuum filtration. The chloroform filtrate was washed with 2 x 10 ml water, then 2 x 10 ml 10% HCl, followed again by 2 x 10 ml H2O. Evaporation of the chloroform afforded the crude anilide. In some cases a considerable amount of anilide product occluded with the aniline hydrochloride that was filtered from the reaction mixture. In those instances, the solid from the reaction mixture was dried, stirred vigorously with 100 ml water for 30 minutes, and then filtered by vacuum. The water insoluble anilide, and the residue from the chloroform evaporation were combined and recrystallized from aqueous ethanol. A second recrystallization was performed to produce a sharp melting analytical sample for C,H,N and spectroscopic analysis.

Figure 1. Structures of the dichloronicotanilides.

and IIb, dry benzene was used as solvent and the reflux time was extended to 1 hour). The reaction mixture was cooled, and the solid collected by vacuum filtration. The chloroform filtrate was washed with 2 x 10 ml water, then 2 x 10 ml 10% HCl, followed again by 2 x 10 ml H2O. Evaporation of the chloroform afforded the crude anilide. In some cases a considerable amount of anilide product occluded with the aniline hydrochloride that was filtered from the reaction mixture. In those instances, the solid from the reaction mixture was dried, stirred vigorously with 100 ml water for 30 minutes, and then filtered by vacuum. The water insoluble anilide, and the residue from the chloroform evaporation were combined and recrystallized from aqueous ethanol. A second recrystallization was performed to produce a sharp melting analytical sample for C,H,N and spectroscopic analysis.
RESULTS AND DISCUSSION

Preliminary experiments showed that the Schotten Bauman method (reaction of the acid chloride with the aniline in the presence of 5% NaOH) was unacceptable for the preparation for these particular anilides, since products were isolated in only trace amounts and were attended by large quantities of intractable material. Therefore, it was decided to conduct the reactions using a 2.25:1 molar ratio of amine to acid chloride, so that the excess amine rather than sodium hydroxide would catalyze the reaction. The transformations were thus accomplished smoothly and without complication.

Yields and melting points of the anilides are reported in Tables 1 and 2. With the exception of compounds 1b and 1a, yields were extremely good. Repeated attempts to improve the yields of the aforementioned anilides proved unavailing and the reason for these exceptions remains unexplained. The melting characteristics of the isomeric anilides followed the general pattern of a higher melting 5,6-dichloro isomer, with the notable exception being the 4-trifluoromethylanilides (lg and fg).

The infrared spectra of the anilides (Tables 1 and 2) revealed the expected sharp single band absorption of the amide N-H stretch in the range 3250 to 3500 cm⁻¹. There does not appear to be a clear trend in the N-H stretch frequencies of pairs of isomers; i.e. where there are large isomeric differences in the lower stretch frequency seems to be equally divided among the 2,6- and 5,6-isomers. Therefore it is not possible to draw any conclusion regarding solid state hydrogen bonding tendencies of the two systems. Strong carbon absorptions were exhibited by all anilides in the expected range of an aromatic amide (1640-1700 cm⁻¹). There are no particular trends noted in isomeric comparisons of these absorption frequencies.

Elemental analyses clearly support the structures of all compounds, since observed C, H, and N percentages are within 0.4% of the calculated values. (Tables 1 and 2).

Table 1. Experimental, Infrared, and Elemental Analysis Data for the 4-Substituted-2, 5-Dichloronicotinamidines (I).

<table>
<thead>
<tr>
<th>Cpd.</th>
<th>Yield</th>
<th>mp°C</th>
<th>IR ν, cm⁻¹</th>
<th>Elemental Anal.</th>
<th>Calc'd % (Found %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a</td>
<td>94.4</td>
<td>147</td>
<td>3494 1647</td>
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<td>10.49 (10.36)</td>
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<tr>
<td>1b</td>
<td>82.6</td>
<td>165</td>
<td>3307 1637</td>
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<td>9.63 (9.36)</td>
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<tr>
<td>1c</td>
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<td>181</td>
<td>3268 1550</td>
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<td>9.80 (9.76)</td>
</tr>
<tr>
<td>1d</td>
<td>77.7</td>
<td>154</td>
<td>3470 1488</td>
<td>8.95 (8.95)</td>
<td>9.82 (9.84)</td>
</tr>
<tr>
<td>1e</td>
<td>72.1</td>
<td>180</td>
<td>3286 1559</td>
<td>9.12 (9.12)</td>
<td>9.07 (9.08)</td>
</tr>
<tr>
<td>1f</td>
<td>67</td>
<td>173</td>
<td>3329 1667</td>
<td>9.54 (9.54)</td>
<td>9.01 (8.93)</td>
</tr>
<tr>
<td>1g</td>
<td>90.2</td>
<td>164</td>
<td>3262 1559</td>
<td>9.44 (9.45)</td>
<td>8.38 (8.50)</td>
</tr>
<tr>
<td>1h</td>
<td>92</td>
<td>167</td>
<td>3237 1592</td>
<td>9.56 (9.56)</td>
<td>8.24 (8.28)</td>
</tr>
</tbody>
</table>

Table 2. Experimental, Infrared, and Elemental Analysis Data for the 4-Substituted-5, 6-Dichloronicotinamidines (II).

<table>
<thead>
<tr>
<th>Cpd.</th>
<th>Yield</th>
<th>mp°C</th>
<th>IR ν, cm⁻¹</th>
<th>Elemental Anal.</th>
<th>Calc'd % (Found %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2a</td>
<td>50.1</td>
<td>162</td>
<td>3359 1657</td>
<td>9.93 (9.93)</td>
<td>10.46 (10.38)</td>
</tr>
<tr>
<td>2b</td>
<td>88.6</td>
<td>186</td>
<td>3329 1668</td>
<td>9.20 (9.20)</td>
<td>9.43 (9.28)</td>
</tr>
<tr>
<td>2c</td>
<td>73.7</td>
<td>179</td>
<td>3401 1648</td>
<td>9.55 (9.55)</td>
<td>9.69 (9.70)</td>
</tr>
<tr>
<td>2d</td>
<td>74.3</td>
<td>163</td>
<td>3254 1644</td>
<td>9.56 (9.55)</td>
<td>9.82 (9.83)</td>
</tr>
<tr>
<td>2e</td>
<td>85.2</td>
<td>152</td>
<td>3344 1677</td>
<td>9.22 (9.22)</td>
<td>8.69 (8.14)</td>
</tr>
<tr>
<td>2f</td>
<td>87</td>
<td>154</td>
<td>3316 1677</td>
<td>9.37 (9.37)</td>
<td>9.06 (9.05)</td>
</tr>
<tr>
<td>2g</td>
<td>90.6</td>
<td>166</td>
<td>3333 1682</td>
<td>9.45 (9.45)</td>
<td>8.33 (8.12)</td>
</tr>
<tr>
<td>2h</td>
<td>85.3</td>
<td>165</td>
<td>3327 1685</td>
<td>9.38 (9.38)</td>
<td>13.48 (13.47)</td>
</tr>
</tbody>
</table>

The ¹H nmr spectra of all compounds were very definitive (Tables 3 and 4). Proton integration yielded the expected relative area ratios in all cases. Dimethyl sulfoxide was the solvent of choice, not only for its excellent solvation properties, but also for the fact that amide proton chemical shifts in DMSO were clearly separable from the aromatic region. In CDCl₃ the amide protons were further upfield and often buried in the aromatic proton signals. The downfield chemical shifts in DMSO were nearly 6.9-8.5 ppm. The lower field signal was assigned to the H₂ protons except in the case of the 4-mitro derivatives 1b and 1h where H₃ was the more deshielded proton set. In the cases of the 4-fluro-derivatives 1d and 1d, proton coupling with fluorine produced triplets for the protons in position 3. In the i series of anilides the vicinal protons in the 4 and 5 positions on the pyridine ring gave rise to AB doublets (J = 8 Hz). The lower field signal was assigned to H₄ due to its closer proximity to the amide function. In the II series of anilides the meta-oriented protons at H₃ and H₄ had the expected small coupling constant of 2 Hz. The H₂ proton was deshielded to nearly 8.9 ppm in all cases because of its position between the ring nitrogen and the amide group. It is noteworthy that the chemical shift of H₃ is further downfield in the II series when the chlorine is in position 5, than in the I series where the 5 position is unsubstituted. This is to be expected, and offers further evidence that the pyridine proton assignments are correct.

Table 3. ¹H NMR Chemical Shift Data (δ ppm) for the 4-Substituted-2, 5-Dichloronicotinamidines (I).

<table>
<thead>
<tr>
<th>Cpd.</th>
<th>Amide</th>
<th>Pyridine</th>
<th>Benzene</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Protons ²</td>
<td>Protons ³</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>δ H₂</td>
<td>δ H₃</td>
<td>δ H₄</td>
</tr>
<tr>
<td>1a</td>
<td>10.69</td>
<td>8.19</td>
<td>7.74</td>
<td>7.71</td>
</tr>
<tr>
<td>1b</td>
<td>10.53</td>
<td>8.16</td>
<td>7.72</td>
<td>7.60</td>
</tr>
<tr>
<td>1c</td>
<td>10.50</td>
<td>8.17</td>
<td>7.73</td>
<td>7.57</td>
</tr>
<tr>
<td>1d</td>
<td>10.75</td>
<td>8.19</td>
<td>7.76</td>
<td>7.67</td>
</tr>
<tr>
<td>1e</td>
<td>10.83</td>
<td>8.20</td>
<td>7.76</td>
<td>7.66</td>
</tr>
<tr>
<td>1f</td>
<td>11.02</td>
<td>8.23</td>
<td>7.80</td>
<td>7.76</td>
</tr>
<tr>
<td>1g</td>
<td>11.06</td>
<td>8.24</td>
<td>7.90</td>
<td>7.78</td>
</tr>
<tr>
<td>1h</td>
<td>11.10</td>
<td>8.26</td>
<td>7.77</td>
<td>7.76</td>
</tr>
</tbody>
</table>

² singlet; ³:2:1 doublets with J = 8 Hz; ⁴:1:1 doublets with J = 8.5-9.0 Hz unless otherwise indicated.

Table 4. ¹H NMR Chemical Shift Data (δ ppm) for the 4-Substituted-5, 6-Dichloronicotinamidines (II).

<table>
<thead>
<tr>
<th>Cpd.</th>
<th>Amide</th>
<th>Pyridine</th>
<th>Benzene</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Protons ²</td>
<td>Protons ³</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>δ H₂</td>
<td>δ H₃</td>
<td>δ H₄</td>
</tr>
<tr>
<td>1a</td>
<td>10.56</td>
<td>8.91</td>
<td>8.53</td>
<td>7.79</td>
</tr>
<tr>
<td>1b</td>
<td>10.43</td>
<td>8.89</td>
<td>8.53</td>
<td>7.63</td>
</tr>
<tr>
<td>1c</td>
<td>10.48</td>
<td>8.89</td>
<td>8.62</td>
<td>7.63</td>
</tr>
<tr>
<td>1d</td>
<td>10.59</td>
<td>8.91</td>
<td>8.61</td>
<td>7.68</td>
</tr>
<tr>
<td>1e</td>
<td>10.65</td>
<td>8.91</td>
<td>8.65</td>
<td>7.73</td>
</tr>
<tr>
<td>1f</td>
<td>10.82</td>
<td>8.91</td>
<td>8.64</td>
<td>7.73</td>
</tr>
<tr>
<td>1g</td>
<td>10.86</td>
<td>8.91</td>
<td>8.66</td>
<td>7.76</td>
</tr>
<tr>
<td>1h</td>
<td>11.04</td>
<td>8.91</td>
<td>8.69</td>
<td>0.00</td>
</tr>
</tbody>
</table>

² singlet; ³:2:1 doublets with J = 2 Hz; ⁴:1:1 doublets with J = 8.5-9.0 Hz unless otherwise indicated. s = singlet, t = triplet, m = multiplet.

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ACKNOWLEDGMENTS

The author gratefully acknowledges the UALR Faculty Research Fund for partial support of this work and Mr. Alan D. Toland for his help in obtaining the $^1$H nmr spectra.

LITERATURE CITED


HAMMETT CORRELATIONS IN THE $^1$H NMR SPECTRA OF SOME N-ARYLDIHALONICOTINAMIDES

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Department of Chemistry
University of Arkansas at Little Rock
Little Rock, AR 72204

ABSTRACT

Excellent linear correlations of amide proton chemical shifts ($\delta_{\text{NH}}$) (in DMSO-$d_6$) with Hammett substituent constants ($\rho$) for a series of 4-substituted anilides of four dihalonic acid systems were observed. Dihalonic anilides with chlorine in the pyridine 2-position exhibited a more positive slope in a Hammett plot of $\delta_{\text{NH}}$ vs. $\sigma_R$, where $R$ is the substituent in the 4-position of the benzene ring. This observation is explained in terms of the inductive effect of chlorine which results in a slightly more acidic amide proton, which in turn causes an enhanced hydrogen bonding tendency to solvent. Four disubstituted anilides were also prepared, and the $\delta_{\text{NH}}$ of these derivatives correlated well with the additive value of the $\sigma^H_R$'s of the two substituents.

INTRODUCTION

The Hammett equation (Jaffe, 1953) has been used for many years to assess the electronic effects of substituents ($R$) through an ary system on a reaction site ($Y$). Substituents located in the 2-position with respect to $Y$

are normally not studied to avoid any complication by steric effects. The equation normally takes the form:

$$\log k = \rho \sigma R + \log k_0$$

where $k$ is the rate constant of the reaction being studied with different $R$ substituents present, and $k_0$ is the corresponding rate constant of the unsubstituted compound ($R = H$). The substituent constant $\sigma R$ is a value determined from a standard reaction and is characteristic of the nature and position of the substituent. If the substituent is electron withdrawing $\sigma_R$ has a value $> 0$, and a value $< 0$ indicates an electron donating substituent. The reaction constant $\rho$ is characteristic of a given reaction and denotes the sensitivity of the reaction to substituent effects. It has a positive value if the reaction is enhanced by electron withdrawing substituents, and a negative value if the reaction is facilitated by electron releasing groups. Thus, insight into the polar nature of the transition state of the rate controlling step of a reaction may be obtained. A value for $\rho$ may be determined graphically by plotting $\log k$ vs. the known value for $\sigma R$ and calculating the slope of the line.

There have been many successful as well as unsuccessful attempts to correlate properties other than reaction rates with the Hammett $\sigma R$ values (Exner, 1988). Properties such as ultraviolet and infrared absorption frequencies and intensities as well as biological activities have met with only limited success. However, correlations of $^1$H NMR data with substituent constants have generally proved more rewarding (Ewing, 1978). Most relevant to this study is the reported correlation of substituent effects in a series of substituted acetanilides and phenylureas (Guifney and O'Connor, 1975).

RESULTS AND DISCUSSION

We have reported previously the preparation and complete structural characterization of several N-(4-substituted phenyl)amides of 5-bromo-6-chloro- and 5-bromo-2-chloronicotinic acid (Setliff and Caldwell, 1991) and of 2,6-dichloro- and 5,6-dichloronicotinic acid (Setliff and Soman, 1992). These compounds correspond to amide series IV, III, I and II as depicted in Figure 1. The $R$ substituents are designated in Table I by letters. Having available such a closely related series of compounds we reasoned that there might be noticeable trends in their $^1$H NMR spectra.
which could be related to transmission of electronic effects through the benzene and/or pyridine ring. In this regard we were able to correlate the amide proton chemical shifts of the R-substituted N-aryldihalonicotinamides within all four dihalamide series with the standard Hammett $\sigma_R$ values. Chemical shift values (SNH) and $\sigma_R$ values (Exner, 1988) are summarized in Table 1, and the excellent linear correlations are shown in Figures 2 and 3. Results of the linear regression analysis of these data are summarized in Figure 1 together with the correlation equation in slope intercept form. The slope of the line is interpreted as the Hammett $\rho$ value.

Figure 2. Hammett Plots of the 4-Substituted phenylbromo-
chloronicotinamides.

Figure 3. Hammett Plots of the 4-Substituted phenyldichloro-
chloronicotinamides.

The positive $\rho$ values in all four series indicate a sensitivity to electron withdrawing groups and that greater deshielding of the amide proton is occurring as the electron withdrawing power of the R substituent increases. Such deshielding is the result of the more efficient hydrogen bonding of the amide proton with the DMSO solvent as the proton is rendered more acidic by the transmission of electron density away from the amide nitrogen atom. For those electron withdrawing groups capable of withdrawing electron density by a resonance effect (CN and NO$_2$) the refined Hammett $\sigma^*$ values (Exner, 1988) which allow for "through conjugation" did not correlate at all. This suggests that the resonance effect is negligible and that the electron withdrawing process is chiefly one of simple induction.

A positional effect of the chlorine on the pyridine ring is noteworthy. With the chlorine in the pyridine 2-position (amide systems I and III) we note a larger $\rho$ value than in amide systems II and IV where the chlorine is in the 6-position. The larger $\rho$ value is attributed to the greater electron withdrawing inductive effect of the chlorine in the 2-position by virtue of its closer proximity to the amide nitrogen. This constant acidity enhancement throughout the series results in a greater hydrogen bonding sensitivity to the transmission of electron density by R groups in the 4-position of the benzene ring. Thus, in the Hammett context, this greater sensitivity should predict a $\rho$ value (slope) of greater magnitude.

In cases where there are more than one substituent on a benzene ring operating on a reaction center, the effects of the substituents may be generally shown to be additive (Exner, 1988). In order to test our model for additive substituent effects we prepared the N-(3-chloro-4-methoxyphenyl)dihalonicotinamides III and IV, and the N-(4-bromo-3-methylphenyl)dihalonicotinamides III and IV. Their amide proton chemical shifts are listed in Table 2. If the substituent effects are additive, the algebraic sum of the two $\sigma_R$ values when substituted in the correlation equation should yield a calculated $\delta_{SNH}$ reasonably close to the observed chemical shift. The results are summarized in Table 2. Agreement of the calculated and observed $\delta_{SNH}$ values are all within 0.08 ppm, which indicates acceptable additive predictability.

Table 2. Additive Substituent Effects. Comparison of Observed $\delta_{SNH}$ (ppm) to Calculated Values.

<table>
<thead>
<tr>
<th>Cpd.</th>
<th>substituents</th>
<th>$\alpha_R$</th>
<th>$\delta_{SNH}$ series III</th>
<th>$\delta_{SNH}$ series IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>3-Cl, 4-OC$_3$H$_7$</td>
<td>0.99</td>
<td>10.72</td>
<td>10.76</td>
</tr>
<tr>
<td>b.</td>
<td>4-Br, 3-C$_6$H$_4$</td>
<td>0.16</td>
<td>10.78</td>
<td>10.81</td>
</tr>
</tbody>
</table>

MATERIALS AND METHODS

All $^1$H NMR spectra were determined on a Bruker 200 MHz FTACF superconductivity spectrometer equipped with ASPECT 3000 computer control. Extremely sharp melting crystalline samples of all compounds were used in the $^1$H NMR analyses, and were dissolved in analytical grade DMSO-$d_6$ containing 1% tetramethylsilane. Sample concentrations were 20 mg per ml of solvent.

Hammett plots were done on a Zenith 248 computer using an Axum least squares linear fit program available from Tririmetrix, Inc. Seattle Washington.

The N-(disubstituted phenyl) dihalonicotinamides were prepared from the dihalonicotinic acids via their respective dihalonicotinyl chlorides and the appropriately disubstituted anilines by general procedures already described (Setliff and Caldwell, 1991). Their structures were confirmed by elemental analysis (Desert Analytics Tucson, Arizona) as well as by infrared and $^1$H NMR spectroscopy. Experimental data are summarized below. All compounds were recrystallized from aqueous ethanol, and all $^1$H NMR proton signals were observed in the correct area ratios.

N-(3-Chloro-4-methoxyphenyl)-5-bromo-2-chloronicotinamide (III) was obtained in 95% yield, m.p. 158°C. IR: v 3299(NH), 1643(C=O)cm$^{-1}$. $^1$H NMR: $\delta$ 10.72 (s) amide H, 8.71 (d) pyridine H4, (d) pyridine H6, 7.85 (d) benzene H2, 7.53 (d of d) benzene H6, 7.17 (d) benzene H5, 3.85 (s) OCH$_3$. Anal. calc'd for C$_{13}$H$_8$N$_2$O$_3$BrCl: %: C, 41.52; H, 2.31; N, 7.29.

N-(3-Chloro-4-methoxyphenyl)-5-bromo-6-chloronicotinamide (IV) was obtained in 82% yield, m.p. 218°C. IR: v 3277(NH), 1643(C=O)cm$^{-1}$. $^1$H NMR: $\delta$ 10.52 (s) amide H, 8.91 (d) pyridine H4, 8.71 (d) pyridine H6, 7.90 (d) benzene H2, 7.64 (d of d) benzene H6, 7.2 (d) benzene H5, 3.85 (s) OCH$_3$. Anal. calc'd for C$_{13}$H$_8$N$_2$O$_3$BrCl: %: C, 41.52; H, 2.41; N, 7.45. Found: C, 41.72; H, 2.28; N, 7.41.

N-(4-Bromo-3-methylphenyl)-5-bromo-2-chloronicotinamide (III) was obtained in 82% yield, m.p. 182°C. IR: v 3252(NH), 1664(C=O)cm$^{-1}$. $^1$H NMR: $\delta$ 10.78 (s) amide H, 8.72 (d) pyridine H4, 8.46 (d) pyridine H6, 7.70 (benzene H2), 7.5 (d) benzene H6, 7.45 (d of d) benzene H5, 2.35 (s) CH$_3$. Anal. calc'd for C$_{13}$H$_8$N$_2$O$_3$BrCl: %: C, 38.60; H, 2.24; N, 6.93. Found: C, 38.42; H, 2.21; N, 6.86.
N-(4-Bromo-3-methylphenyl)-5-bromo-6-chloronicotinamide (IVk)-obtained in 60% yield, m.p. 192°C. IR: ν 3277 (NH), 1643 (C=O) cm⁻¹. ¹H NMR: 8 10.55 (s) amide H, 8.90 (d) pyridine H₃, 8.70 (d) pyridine H₄, 7.74 (s, b) benzene H₇, 7.55 (m) benzene H₅ and H₆, 2.34 (s) CH₃. Anal. Calc’d for C₂₃H₁₉N₂OBr₂Cl(%): C, 38.60; H, 2.24; N, 6.93. Found: C, 38.58; H, 2.22; N, 6.70.

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The authors gratefully acknowledge the UALR Faculty Research Fund for partial support of this work and Mr. Alan Toland for his help in obtaining the ¹H NMR spectra.

LITERATURE CITED


APPLICATION OF STABLE OPERATING CRITERION TO GRATING TUNED STRONG EXTERNAL FEEDBACK SEMICONDUCTOR LASERS

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2801 South University Avenue
Little Rock, AR 72204.

ABSTRACT

Stability analysis is done by applying criterion \( \frac{\partial \gamma}{\partial \omega} = 0 \) for grating tuned strong external feedback semiconductor lasers. The resulting stable and unstable operating ranges agree well with experimental results.

INTRODUCTION

Much attention has been paid to external feedback semiconductor lasers since 1980 (Lang et al., 1980), and recently to grating tuned strong external feedback semiconductor lasers because of their applications as narrow linewidth, frequency tunable emission sources in coherent optical communication systems (Yamamoto et al., 1981; Wyatt et al., 1985; Glas et al., 1982; Zorabedian et al., 1987; Sun et al., 1990). Strong external feedback is defined as the case when the reflectivity of the external feedback reflector is larger than the reflectivity of laser diode's internal facet which is close to the external reflector. For strong external feedback semiconductor lasers, experimental results on bistable tunings of both emission power versus operating electrical current and emission power versus operating laser light frequency have been reported (Glas et al., 1982; Zorabedian et al., 1987). Steady state solutions show that there are three-value tuning curves of threshold gain (or emission power) versus operating electrical current, and of threshold gain versus operating laser light frequency (Glas et al., 1982; Zorabedian et al., 1987). However, steady state solutions can not explain why the middle value tuning curves are unstable as shown by experimental results. There is a general stable operating criterion \( \frac{\partial \gamma}{\partial \omega} = 0 \) for external cavity semiconductor lasers (Tromborg et al., 1987), where \( \omega_0 \) is the resonant frequency of the semiconductor laser without external feedback and \( \omega \) is the operating frequency of the semiconductor laser with external feedback. Glas et al. (1982) applied this criterion to the first case of threshold gain versus operating current tuning curves. They found that the middle value tuning curve was unstable. As far as we know there is still no one who applies this criterion to the second case of threshold gain versus operating frequency tuning curves in order to determine if the middle value tuning curve is stable. In this paper we present our application of this general stable operating criterion to the second case of threshold gain versus operating frequency tuning curves.

THEORY

Figure 1 shows schematically a typical setup of an grating external feedback semiconductor laser. A Littrow grating is used as the external optical feedback reflector. The semiconductor laser and the grating compose a compound cavity laser. For simplicity the grating is assumed to be a frequency filter reflector with an amplitude reflectivity \( r_2 \) for frequencies within the filter range and a zero reflectivity for frequencies outside the filter range (Zorabedian et al., 1987). The filter range can be tuned by tuning the reflecting angle of the grating. The semiconductor laser has its internal facet antireflection coated with an amplitude reflectivity of \( r_2 < r_3 \). The effective reflectivity of the external cavity composed of \( r_2 \) and \( r_3 \) is (Zorabedian et al., 1987)

\[
\gamma = \left( \frac{r_2 + r_3 \exp(-i\omega_0)}{1 + r_2 r_3 \exp(-i\omega_0)} \right) \exp[i \arg(r_3)],
\]

where \( \omega_0 \) is the operating frequency of the semiconductor laser with external feedback (or the operating frequency of the compound cavity laser), \( \omega_0 = 2\pi f_0/c \) is the light round trip time in the external cavity, \( l_0 \) is the length of the external cavity and \( c \) is the light velocity in vacuum.

The steady state solution can be obtained from the compound cavity laser field equations (Zorabedian et al., 1987)

\[
g = -\frac{1}{\lambda_0} \ln(r_1 | r_1 |)
\]

\[
\omega - \omega_0 = -\frac{1}{\lambda_0} \arg(r_3)
\]

where \( g \) is the threshold gain, \( f_0 \) is the semiconductor laser cavity length, \( r_1 \) is the amplitude reflectivity of another facet of semiconductor laser, \( \lambda_0 = \frac{pc}{n} \) is the resonant frequency of the semiconductor laser with external feedback, \( n \) is the refractive index of the semiconductor laser active medium with external feedback, \( \omega_0 = 2\pi f_0/c \) is the light round trip time in semiconductor laser with external feedback and integer \( p \) is the mode number. The refractive index of laser diode without external feedback \( \lambda_0 \) is related to \( n \) by (Zorabedian et al., 1987)

\[
n - n_0 = \frac{\alpha c}{2\lambda_0} (g - g_0)
\]

where \( \alpha \) is the linewidth enhancement factor (Henry, 1982) and \( g_0 = -\delta(t_1 r_2)/r_3 \) is the threshold gain of the semiconductor laser without external feedback. We now have three equations (2), (3) and (4) and three

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unknown parameters \( \alpha, g \) and \( n \). Combining eq(3) and (4) to eliminate \( n \) we obtain

\[
g = \left( \frac{1}{\alpha} \right) \left( \frac{\alpha_0 - \alpha}{\alpha_0 - \alpha_0} \right) \left( -1 / \alpha \right) \left| \ln(r_2) \right|
\]

(5)

where \( r_2 = 2n_0 \left| \frac{\partial \alpha}{\partial n} \right| \) is the light round trip time of the semiconductor laser without external feedback \( \alpha_0 = \left( \frac{\partial c}{\partial n} \right) \) is the resonant frequency of the semiconductor laser without external feedback. Combining eq(2) and (5) to solve for \( g \) and \( \alpha \) we obtain the threshold gain operating frequency tuning curves shown in Fig. 2 for various values of \( r_2 \) and fixed values of \( r_2 = 0.5, r_2 = 0.5, \alpha = -7, \beta = 0.33, n_0 = 3, \zeta = 90\text{mm} \) and for a frequency range between \( \alpha_0/2\pi = p + 1 \) and \( \alpha_0/2\pi = p + 1 \). There are 100 solutions when the grating filter is tuned over this frequency range since \( \zeta = 100\alpha_0/2\pi \). In Fig. 2 four curves associated with different values of \( r_2 \) are displayed. Curve A shows that for a large value there appear three-value tuning curves within a certain frequency range (for a larger \( r_2 \) or a smaller \( \alpha \) there is a larger critical value of \( r_2 \) which is about 0.1 in our case). Experimental results showed (Zorabedian et al., 1987) that the operating points along tuning curve A between marks \( s \) and \( u \) are unstable and the other operating points along the two tuning curves between marks \( s \) and \( u \), are stable, these two tuning curves compose bistable tuning (Zorabedian et al., 1987). But the steady state solution can not explain this phenomenon.

In the following we carry out a stability analysis by applying the general stable operating criterion

\[
d\alpha_0(\omega)/d\omega > 0
\]

(6)

to the steady state solutions to see what happens. Combining eq(2) and (5) to eliminate \( g \) we have

\[
d\alpha_0(\omega) = \alpha - \alpha \beta \left( \frac{\alpha_0}{r_2} \right) + \arg(r_2) + \alpha_0/\alpha_0
\]

(7)

which is just what we want for stability analysis. Inserting eq(7) into (6) results in, for curve A, the stable operating points between marks \( u \) and \( s \), and the unstable operating points between marks \( u \) and \( s \) as shown in Fig. 2. This result agrees well with the experimental result (Zorabedian et al., 1987). Applying the criterion to curve B, we find that the stable and unstable operating points are also between marks \( u \) and \( s \), and marks \( u \), \( u \) respectively. All the operating points on curves C and D are stable. We know that there exist experimental results showing that for a very small value of \( r_2 \) the tuning curve (something like curve D) is completely stable. However, as far as we know, there is no corresponding experimental result for a large value of \( r_2 \) since an accurate measurement of the value of \( r_2 \) is not easy. Therefore we do not know at this stage how well the experimental and our theoretical results for tuning curve B and C agree. We note that the criterion \( d\alpha_0(\omega)/d\omega > 0 \) is necessary but not sufficient for stable operation (Tromborg et al., 1987). That is, there may be other types of instability or chaotic behavior for operating points which satisfy the stable operating criterion. We also note that the advantage of this stability analysis is that it is simple. However, the physical mechanism of stable, unstable and bistable tuning is not very clear.

**DISCUSSION**

We have carried out (Sun et al., 1992) a direct stability analysis from eq(2) and (5) by introducing a small fluctuation in refractive index \( \Delta n(\omega) \) and studying the resulting time evolution. We find that the first small fluctuation in refractive index \( \Delta n(\omega) \) will cause the second fluctuation \( \Delta n(\omega) \) which will cause the third order \( \Delta n(\omega) \) and so on. If for one operating point the condition \( \Delta n(\omega) > \Delta n(\omega) \) where \( i \) is any integer, is always true (or always false), the fluctuation will be damped (or amplified) and this operating point is stable (or unstable). Using this stable operating criterion to judge all the operating points of curves A, B, and D result in the same stable and unstable operating ranges, but for curve C it results in a small unstable range shown by thick line. Until now one could not explain the different results for curve C. However the direct stability analysis presented there provides a straightforward insight into, and a clear explanation for, the stable, unstable, and bistable operating of grating tuned strong external feedback semiconductor lasers.

**LITERATURE CITED**


THE EFFECT OF AEROSOLS ON CLIMATE CHANGE

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ABSTRACT

A modified two-stream approximation is presented, which includes the effect of solar zenith angle and is applicable to study the effect of aerosols on both regional and global climate changes. More realistic results are derived. A reasonable critical value of 0.8 for aerosol single scattering albedo to determine whether the aerosols will heat or cool the climate is derived.

INTRODUCTION

In recent years much attention has been devoted to the role of atmospheric aerosols in the thermal state of the earth-atmosphere system. These investigations have been motivated by the possibility that there is a connection between observed climatic trends and a general buildup of atmospheric aerosols in large geographical areas. It is believed that the absorption of solar radiation by an aerosol layer increases the radiative heating of atmosphere, while the backscattering decreases the total amount of energy available to the earth. Chylet et al. (1974) assumed the aerosol layer to be a plane-parallel layer, and used a radiative transfer equation to describe the scattering and absorption effects of aerosols. But this equation was integro-differential and could not be solved analytically. They used a two-stream approximation to solve this equation and found the effect of aerosols on climate change to be a function of aerosol layer optical thickness t, aerosol single scattering albedo w and the earth albedo a. They also stated that "this form of two-stream approximation is applicable only to globally averaged conditions. It does not include the dependence of the heating on the solar zenith angle which is necessary for the study of regional heating effects". In this paper we modify the work of Chylet et al., (1974) in two aspects: (1) we consider the effect of aerosols on regional climate change by including the effect of solar zenith angle, and (2) we consider the effect of aerosols on global climate change by treating the aerosol layer to be a ball crust layer around the earth instead of to be a plane layer, and including the effect of solar zenith angle. Therefore we obtain more realistic results. We also use our modified two-stream approximation to derive a reasonable critical value of aerosol single scattering albedo w in order to determine whether the aerosols will heat or cool the climate.

THEORY

The radiative transfer equation describing the scattering and absorption effects of aerosols was (Chylet et al., 1974)

\[ \frac{dI(\mu)}{dt} = I(\mu) - \frac{1}{2} \int_{-1}^{1} p(\mu, \mu') I(\mu') d\mu' \]

(1)

where \( I(\mu) \) was the specific radiation intensity at optical thickness \( t \), \( \mu = \cos \theta \), and \( \theta \) was the direction with respect to the normal of layer's surface, and \( p(\mu, \mu') \) was an appropriate phase function. To determine, \( R \), the albedo of the combined system of earth and an additional aerosol layer, Chylet et al., (1974) used a two-stream approximation by assuming that the radiative intensity in an aerosol layer was isotropic over the upper hemisphere \( (\mu > 0) \) with the value \( I_0(t) \) and over the lower hemisphere \( (\mu < 0) \) with the corresponding value \( I_0(t) \). \( I(t) \) and \( I_0(t) \) are shown in Figure 1. Consequently, the radiative transfer equation could be transformed into a set of two coupled first order differential equations (Chylet et al., 1974)

\[ \frac{1}{2} I(t) \frac{dI(t)}{dt} = I_0(t) - (1 - \beta)I(t) - \beta I_0(t) \]

(2)

\[ -\frac{1}{2} I(t) \frac{dI(t)}{dt} = I_0(t) - (1 - \beta)I(t) - \beta I_0(t) \]

(3)

where \( \beta \) is the backscattering coefficient. By definition, the albedo \( R \) is determined by the relation \( I(0) = R I_0(t) \) where \( I_0(t) \) is the solar radiation incident vertically on the top of the aerosol layer. The heating caused by an additional aerosol layer is given by the albedo change \( a = R \), where \( a \) is the albedo of the earth. By solving (2) and (3), one can find (Chylet et al., 1974)

\[ a = R = \frac{2(1 - \alpha) - (1 - \alpha)^2\beta}{[1(1 - \alpha) + (1 - \alpha)\alpha + \alpha/2\tan(\alpha)]} \]

(4)

Figure 1. The plane-parallel aerosol layer and the two-stream radiation intensity \( I_0(t) \) and \( I(t) \) as a function of optical thickness \( t \) in the aerosol layer. \( I_0(t) \) is the solar radiation intensity which is vertically incident on the top of the aerosol layer, \( I_0(t) \) is the intensity of backscattering radiation.
where \( \alpha = 2(1-\omega)/(1+\omega+2\beta \omega)1/2 \) and the solar zenith angle is assumed to be zero. The sign of (4) determines whether an aerosol layer will heat or cool the earth-aerosol system. Since the denominator of (4) is always positive, heating occurs if

\[
(1-\omega) / (1-\omega)^2 = 12a
\]

(5)

The solid line curves in Fig. 2a and 2b show the albedo change by the additional aerosol layer as a function of optical thickness \( t \) for various values of \( a \), with \( \beta \omega = 0.1 \) and \( \omega = 0.9 \) and \( \omega = 0.99 \) respectively.

Figure 2a. Solid line curves: two-stream model albedo change \( a - R \) caused by an additional aerosol layer as a function of optical thickness \( t \) for a backscattering coefficient \( \beta \omega = 0.1 \), aerosol single scattering albedo \( \omega = 0.9 \) and for various values of earth albedo \( a \). Dash line curves: modified two-stream model albedo change \( a - R \) caused by an additional aerosol layer for the same parameters as those used for the solid line curves.

Figure 2b. Solid line curves: two-stream model albedo change \( a - R \) caused by an additional aerosol layer as a function of optical thickness \( t \) for a backscattering coefficient \( \beta \omega = 0.1 \), aerosol single scattering albedo \( \omega = 0.99 \) and for various values of earth albedo \( a \). Dash line curves: modified two-stream model albedo change \( a - R \) caused by an additional aerosol layer for the same parameters as those used for the solid line curves.

Our work is as follows. For a regional situation, the aerosol layer can be treated as a plane-parallel layer shown in Fig. 3. But the solar radiation incident angle changes from \(-\pi/2\) to \(\pi/2\) during the day time. Therefore the effect of solar zenith angle must be included for a more accurate calculation. We assume that the intensity of solar radiation incident on the top of the aerosol layer at angle \( \theta \) to be I(\theta) = I_0 cos\theta because the intensity attenuated by the atmosphere path is proportional to cos\theta. The albedo \( R \) becomes a function of \( \theta, R(\theta) \). The aerosol layer can be treated as the sum of many small pieces of aerosol layer shown in Fig. 3 by dash lines. For a given point in the aerosol layer, the optical thickness \( t' = t \cos\theta \) shown in Fig. 3. There is no significant error if the aerosol layer pieces are small enough. Using the two-stream approximation for every small piece of aerosol layer we obtain a modified equation

\[
a - R(\theta) = \left[2a(1-\omega)-(1-\omega)^2 \beta \omega \right] / \left[(1-\omega)+(1-\omega)\beta \omega + \omega^2 \tan^2(\omega \cos \theta) \right]
\]

(6)

where we take the direction of incident radiation to be the normal direction thereby (6) is independent of azimuthal angle, and assume that \( a \) is not a function of \( \theta \). The average albedo change \( a - R \) for one day is

\[
a - R = \int \left[ a - R(\theta) \right] \cos \theta d\theta / \int \cos \theta d\theta
\]

(7)

The integration range from \(-\pi/2\) to \(\pi/2\) is corresponding to sun rise and sun set. It is difficult to solve (7) analytically, but we can solve it numerically. The numerical results of (7) which include the effect of solar zenith angle are shown by dash line curves in Fig. 2a and 2b for the same parameters as those used for the solid line curves in Fig. 2a and 2b. We can see that there are apparent differences between the solid line curves and dash line curves in Fig. 2. The dash line curves obtained from our modified equation are not so widely spread as the solid line curves are, which are obtained from the unmodified two-stream approximation. This difference means that the effect of aerosol on climate change obtained by us is relative weak. This result of ours is logical because our modification includes the effect of solar zenith angle and the solar radiation intensity is weak in the morning and evening times, consequently the heating or cooling of aerosols are weak. From (7) we can find that the critical condition given by (5) for determining whether the aerosols will heat or cool the climate does not change.

When considering the effect of aerosols on the global climate change, the aerosol layer should no longer be considered as a plane layer, but should be a ball crust layer around the earth surface shown in Fig. 4. At
any given time the solar radiation is incident on the top of the aerosol layer at different angles depending on the incident positions. The spatial average albedo change $a - R$ can be obtained from equation

$$a - R = \int \int [a - R(\theta)] \cos \theta d\theta$$

where $\theta$ is the polar angle and $\phi$ is the azimuthal angle. (8) is the same as (7) because the situation is symmetry about the solar radiation incident direction and independent of $\phi$. The situation for the global aerosol effect becomes the same as that for the regional aerosol effect. For a global aerosol effect we take a spatial average, while for a regional aerosol effect we take a time average. Thus the results shown by the dash line curves in Fig. 2 obtained from (7) for the regional aerosol effect can be taken as the results for the global aerosol effect.

Fig. 5 shows the dependence of earth albedo $a$ on the earth surface structure (Chylet et al., 1974). Using the following data: oceans occupy 70% of the earth surface with albedo $a_o = 0.05$, farmland and urban areas occupy 10% of the earth surface with albedo $a_f = 0.2$, deserts occupy 5% of the earth surface with albedo $a_d = 0.35$, snow and ice occupy 15% of the earth surface with albedo $a_s = 0.7$, and clouds cover 10% of the whole earth surface areas with albedo $a_c = 0.5$, we obtain the average earth albedo

$$a = (a_o * 70\% + a_f * 10\% + a_d * 5\% + a_c * 15\%) * 90\% + a_s * 10\% - 0.2$$

Fig. 6 shows the albedo change $a - R$ obtained from (7) as a function of optical thickness $t$ for different aerosol single scattering albedo $\omega$ and $\phi = 0.1$. We see from Fig. 6 that the critical value of $\omega$ (for $a - R = 0$) to determine whether the aerosols will heat or cool the climate is about 0.8 which agrees well with the result given elsewhere (Hansen et al., 1979). Chylet et al (1974) did not calculate the critical value of $\omega$ in their paper.

$$a = (a_o * 70\% + a_f * 10\% + a_d * 5\% + a_c * 15\%) * 90\% + a_s * 10\% - 0.2$$

**CONCLUSION**

In this paper we modify the two-stream approximation (Chylet et al., 1974) by including the effect of solar zenith angle for regional aerosol effect on climate change, and including the effects of both the solar zenith angle and the earth surface curvature for global aerosol effect on climate change. These modifications widen the applicable range of the two-stream approximation and give more accurate results, but the critical condition for determining whether an aerosol layer will heat or cool climate is not changed. Using our modified model and a global average earth albedo of $a = 0.2$, we obtain a reasonable critical aerosol single scattering albedo value of $\omega = 0.8$ to determine whether aerosol heating or cooling occurs.

**LITERATURE CITED**


DISTRIBUTIONAL SURVEY OF THE BIRD-VOICED TREEFROG, Hyla avivoca (Anura: Hylidae), in Arkansas

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ABSTRACT

A field study of the bird-voiced treefrog, Hyla avivoca, was conducted in Arkansas during the summer of 1991. A total of 75 separate sites in 23 counties was visited. Males with their distinctive whistle-like calls were listened for at night at each site. Breeding colonies of Hyla avivoca were found in four of the six major river basins; the study established three new county records. Currently, this species has been documented at 14 sites in 10 counties; in very few situations were the treefrogs locally abundant (voucher specimens deposited in the Arkansas State University Museum of Zoology). Habitat perturbation and reduction by man within the available wetland habitats have undoubtedly contributed to the extirpation of this species from many potentially-favorable aquatic ecosystems.

INTRODUCTION

The bird-voiced treefrog, Hyla avivoca, has a sporadic and poorly-documented distribution in the three states (Arkansas, Louisiana, and Oklahoma) from which the species is known west of the Mississippi River (Smith, 1966; Krupa et al., 1985; Dundee and Rossmann, 1989; Conant and Collins, 1991). Recent studies by Trauth and Robinette (1990a, b) on the distribution of Arkansas populations of H. avivoca indicate a more extensive range than the one mapped by Conant and Collins (1991). The species generally inhabits large rivers, headwater swamps, and swampy floodplains and lakes in the southern half of the state. The breeding season normally begins in April and ends in August (Mount, 1975; Dundee and Rossmann, 1989).

The first specimens of Hyla avivoca collected in Arkansas were taken from Pope County (Turnspeed, 1976), although audio recordings were available from a site just south of Little Rock (Saline County) as early as 1973 (Davis and Hollenback, 1978). Other than the distributional data summarized by Trauth and Robinette (1990a), no studies have documented (with the use of voucher specimens) additional populations in Arkansas. The objective of the present study was to survey optimal habitats for H. avivoca within the major river basins of Arkansas. This type of survey provides additional baseline data on biological diversity of aquatic ecosystems in the state.

MATERIALS AND METHODS

A total of 75 separate sites in 23 counties in Arkansas was visited at night from 19 May through 5 July, 1991 (Fig. 1). Breeding males with their distinctive whistle-like calls were listened for at each site. Fifty-six male frogs were collected to serve not only as voucher specimens but were also utilized in the analysis of food habits and parasite load. Although each site was searched for females, none was observed during the study. All specimens were deposited in the herpetological collection of the Arkansas State University Museum of Zoology (ASUMZ).

RESULTS AND DISCUSSION

By combining the locality sites for Hyla avivoca recorded in Trauth and Robinette (1990a) with those of the present study, bird-voiced treefrogs are now known to occur in four of the six major river basins (see Smith et al., 1984) occurring in Arkansas. In addition, the present study established three new county records; these localities as well as historic sites for H. avivoca are shown in Fig. 1 (see Appendix I for data on the township, range, and section for all sites visited). The new county records and their map designations are as follows: Faulkner County (13), Lafayette County (14), and Monroe County (10).

Figure 1. Localities (closed circles) in Arkansas which were searched for bird-voiced treefrogs from 19 May through 5 July, 1991. County abbreviations are as follows: AR—Arkansas; AS—Ashley; CA—Calhoun; CH—Chicot; CL—Cleveland; CO—Conway; CR—Crittenden; DA—Dallas; DR—Drew; FA—Faulkner; GR—Grant; JE—Jefferson; LA—Lafayette; LI—Lincoln; MO—Monroe; OU—Ouachita; PE—Perry; PH—Phillips; PO—Pope; SA—Saline; UN—Union; WH—White; WO—Woodruff. New county records (*) and historic sites are numerically labeled as follows: 1) Goose Pond, 2) Goose Pond, 3) Lorance Creek, 4) Ferguson Lake, 5) Cox Creek Lake, 6) White Oak Lake, 7) Ouachita River at Camden, 8) Calion Lake, 9) Louisiana Purchase Historic State Park, 10) vic. *Louisiana Purchase Historic State Park, 11) tributary of West Fork Point Remove Creek, 12) spring Lake, 13) *Flag Pond, and 14) *Lake Erling.
Mississippi River Basin.—Several potential sites in three counties along the Mississippi River were visited. The most promising locality, Wapapoca National Wildlife Refuge in Crittenden County, contained habitats typical for *H. avinova* in other parts of the state. Common anuran species, such as *Acris crepitans*, *Hyla chrysoscelis*, *H. cinerea*, *Rana catesbeiana*, and *R. clamitans* were all breeding there on 20 May. At another site, a swampy floodplain in the St. Francis National Forest (Phillips County), was also ideally suited for bird-voiced treefrogs. *Hyla chrysoscelis*, *R. clamitans*, and *Gastrophryne carolinensis* were also calling there on 23 May. Potential habitat along Lake Chicot (Chicot County) was visited on 1 and had numerous breeding populations of *R. catesbeiana*.

White River Basin.—Although numerous aquatic areas were visited within this drainage, only two contiguous sites in Phillips and Monroe counties yielded *H. avinova*. Both were associated with a headwater swamp located in the vicinity of the Louisiana Purchase Historic State Park (sites 9 and 10). Surprisingly, few males were heard calling at these sites considering the protected status of the park. Site 9, representing the historic site for *H. avinova* within the park (documented by the Arkansas Heritage Commission), and site 10 (1.0 km west of this site) were visited frequently at night during time spent within this basin in order to confirm that environmental conditions were conducive for calling by males throughout the basin. The populations at sites 9 and 10 represent the easternmost ones presently known for the species in Arkansas.

Arkansas River Basin.—*Hyla avinova* have been collected from seven sites in this basin. I failed to find frogs in the swampy habitats along the lower stretches of the Arkansas River drainage in Arkansas and Jefferson counties, although these areas appeared to provide ideal habitat situations; yet, sites 3, 4, and 12 just south of Little Rock (Saline County) and sites farther north along the Arkansas River in Faulkner (13), Conway (2 and 11), and Pope (1) counties supported the large populations of the frog. The largest aggregate of breeding males found during the present study was within a floodplain along the West Fork of Point Remove Creek (site 11) in Conway County. On each of three visits (25 May, 9 June, and 4 July) to this site, calling males were so numerous that samples of specimens were taken within minutes of arrival. Estimates of population size (including unobserved females) were roughly from 100 to 200 individuals. Historic sites 1 and 2, just to the north of site 11, were remote and not visited. Flag Pond (site 13), a new record for *H. avinova*, is one of many swampy floodplain habitats found sporadically distributed along the Arkansas River and represents an "enclave for *H. avinova* surrounded by cultivated fields." Males were calling here on 16 June. Sites 3 and 4 in Saline County are historic sites for the species; males were calling at site 12 (near Spray Lake in Saline County), just southwest of the two above, on 3 June.

Osceola River Basin.—Four historic sites for *H. avinova* (5, 6, 7, and 8) occur in this basin which includes most of southern Arkansas. The Cox Creek Lake site (5) in Grant County was visited to verify the existence of calling males within the upper limits of this region; however, no new sites were discovered within ideal habitats along the Saline River. Aquatic habitats in the vicinity of the lower access points to Seven Devils Swamp (Drew County), likewise, yielded no bird-voiced treefrogs. Also, many other promising swampy areas associated with Bayou Bartholomew in Ashley County (e.g., Lake Gramma, Parkin's Slough, Walker's Slough, and Sawyer Slough) were checked on 2 June without success. The historic sites (6, 7, and 8) were not visited during the present study.

Red River Basin.—The southwesternmost locality (site 14) for *H. avinova* in Arkansas was discovered on 5 July on Lake Erling (Lafayette County). Male choruses were heard on either side of the lake along St. Highway 360. An additional site in northwestern Lafayette County near the Red River (Tom White Lake) was noted by the Arkansas Natural Heritage Commission in 1981, although no voucher specimen was taken. The only other site within this basin in known from the Little River in Arkansas (Krupa et al., 1985; Krupa, 1986).

Summary and Recommendations.—The bird-voiced treefrog is currently known from 14 sites and 10 counties in Arkansas. Populations are distributed discontinuously within four major river basins. In most instances, the species exists in isolated enclaves (e.g., in perennially aquatic floodplains, small lakes, swamps, or sloughs) along major river systems. Population size and structure are variable in the localized demes; the largest aggregate of frogs observed occurred in a floodplain, whereas the smallest was in a headwater swamp. Habitat perturbation and reduction by man within aquatic ecosystems along major aquatic transportation or thoroughfare routes have undoubtedly contributed to the extirpation of this species in many stretches of potentially-favorable riparian habitats. In addition, industrial, municipal, and agricultural waste discharge practices that require or indirectly lead to an aquatic disposal of pollutants will continue to reduce and degrade the availability of the optimal habitat conditions. The present status of the known populations of *Hyla avinova* in Arkansas is uncertain, but the survival requirements of this species are directly related to its habitat preference; i.e., they currently exist in a limited number of favorable aquatic environmental settings. Further alteration of these and similar habitats may result in population declines and total extirpation in some areas. Additional studies into the life history and ecology of this species in Arkansas (i.e., Jamieson et al., in press) may help determine the distribution of any future management efforts that may be needed to retain or protect thriving colonies of frogs. Given the interest in the global reduction of anuran populations and amphibians as a whole, long-term research efforts are a matter of necessity and are in tune with the future of sound conservation policies.

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LITERATURE CITED


APPENDIX I

The following general localities and their township, range, and section (in parentheses) were visited in an attempt to find bird-voiced treefrogs from 19 May through 5 July, 1991. The localities have been grouped according to their respective river basin and county. An asterisk denotes a collection site and includes ASUMZ voucher numbers.

Mississippi River Basin.—CHICOT: Lake Chicot (no T.R.S); CRITTENDEN: Wapanocca National Wildlife Refuge (T9N, R8E, S33, 34); PHILLIPS: St. Francis National Forest (T1S, R5E, S29), Humphrey Slough and St. Hwy 20 (T4S, R2E, S22), Long Lake Bayou and St. Hwy 20 (T3S, R3E, S35), Long Lake Bayou and St. Hwy 20 (T3S, R4E, S23), Long Lake Bayou and St. Hwy 20 (T2S, R5E, S30).

White River Basin.—ARKANSAS: Prairie Bayou at Weber (T6S, R1W, S30), MONROE: White River National Wildlife Refuge and St. Hwy 1 (T4S, R1W, S4; T3S, R1W, S34, 26), Indian Bayou (T3S, R1W, S26), Prairie Cypress Creek and St. Hwy 1 (T3S, R1E, S18), Big Cypress Creek and St. Hwy 1 (T3S, R1E, S5), Little Cypress Creek and St. Hwy 1 (T3S, R1W, S36) (*T1N, R1W, S36; ASUMZ 17766), Little Cypress Creek and U.S. Hwy 49 (T1N, R1W, S27, 21), Cypress Creek and U.S. Hwy 49 (T2N, R2W, S14), PHILLIPS: Little Cypress Creek and St. Hwy 39 (T2S, R1E, S9), Little Cypress Creek and St. Hwy 49 (T1S, R1E, S21), Big Creek and St. Hwy 318 (T3S, R1E, S24), Big Creek and U.S. Hwy 49 (T2S, R2E, S36), Little Cypress Creek and U.S. Hwy 49 (T1S, R1E, S21), Louisiana Purchase Historic State Park (T1S, R1E, S6), Bayou DeVie and St. Hwy 17 (T4N, R2W, S29, 30); WHITE: White River at Georgetown (T6N, R4W, S21); WOODRUFF: Cache River and U.S. Hwy 64 (T8N, R2W, S31), Cache River and St. Hwy 260 (T7N, R2W, S19), Maple Slough (T7N, R3W, S30), Cache Bayou and St. Hwy 262 (T6N, R4W, S1), Seven Mile Lake and St. Hwy 262 (T6N, R4W, S15), Bear Slough and St. Hwy 262 (T6N, R4W, S34), Cache River and St. Hwy 38 (T4N, R3W, S5), Gum Flat Creek and St. Hwy 38 (T4N, R3W, S2).

Arkansas River Basin.—ARKANSAS: Lake Morris (no T.R.S; T7S, R3W, S30), Mill Bayou and St. Hwy 276 (T5S, R4W, S26), Cypress Bayou and St. Hwy 44 (T6S, R2W, S30), Bayou Meto Wildlife Management Area—Cox Creek Lake (T5S, R6W, S2); CONWAY: vic. West Fork of Point Remove Creek (*T7N, R17W, S16; ASUMZ 17799-822; 17733-38; 17770-74; 17787-88; 17920-25); FAULKNER: East Fork Cadron Creek and U.S. Hwy 65 (T6N, R13W, S16), Flag Pond (*T4N, R14W, S21, 22; ASUMZ 17860-67); JEFFERSON: Tar Creek and Arkansas River (T3S, R10W, S17); PERRY: Flat Cypress Creek and St. Hwy 9 (T5N, R17W, S27), Tributary of Bull Slough and St. Hwy 60 (T4N, R17W, S18), Bull Slough (T4N, R17W, S19); SALINE: Spring Lake Rd. at Spring Lake (*T2S, R12W, S7; ASUMZ 17767-69);


Red River Basin.—LAFAYETTE: Lake Erling and St. Hwy 360 (*T1S, R24W, S9, 10; ASUMZ 17926-32), Slough and St. Hwy 360 (T18S, R25W, S14), Poteau Bayou and St. Hwy 160 (T19S, R25W, S8).
STATUS OF THE OZARK HELLBENDER, CRYPTOBRANCHUS BISHOPI (URODELA: CRYPTOBRANCHIDAE), IN THE SPRING RIVER, FULTON COUNTY, ARKANSAS

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ABSTRACT

We conducted a tag and release study of the Ozark hellbender along a 26 km stretch of the Spring River from mid-July through mid-November, 1991, to determine current population levels. Salamanders were collected by hand with the aid of scuba diving equipment. Thirteen visits (36 dive hrs.) to 10 selected access sites yielded 20 animals. Compared to previously published data of the early 1980's which indicated large, thriving populations of C. bishopi (in some cases, > 300 individuals) in the Spring River, our study found perilously low numbers of salamanders. This drastic decline may be attributed to overcollection of specimens for scientific or other purposes and habitat alteration related to recreational activities. Other contributing factors for this decline could be the inadvertent killing of animals during human activity (seining, swimming, canoeing, and fishing), the elimination of riparian habitats leading to an increase in the silt burden, and water pollution associated with human occupation and development along the river.

INTRODUCTION

The Ozark hellbender, Cryptobranchus bishopi, is a large, long-lived, aquatic salamander endemic to several river drainage systems in the Ozark Mountains of southern Missouri and northern Arkansas (Conant and Collins, 1991; Dundee, 1971). Prior to impoundment of the White River, the known distribution of this species (formerly C. alleganiensis bishopi; see Collins, 1991) in Arkansas included the North Fork of the White River in Baxter County as well as portions of the Spring and Black rivers in Fulton, Randolph, and Sharp counties (Dundee, 1971). Although Dundee (1971) indicated on his distributional map the presence of C. bishopi along the Arkansas-Missouri border in Arkansas, no mention is given to any specific localities other than the Spring River. At present, the only documented populations of C. bishopi in Arkansas are those that occur in the upper reaches of the Spring River (Dundee and Dundee, 1965; Nickerson and Mays, 1973b; Peterson, 1985). However, recent sightings suggest that the salamander may still occur in the White River and smaller tributaries feeding the Black, Current, Eleven Point, and Spring rivers of Arkansas.

Dundee and Dundee (1965) and Nickerson and Mays (1973a) provided the earliest ecological studies of the Ozark hellbender; Dundee (1971) and Nickerson and Mays (1973b) summarized the literature on the species. Significant recent investigations into the biology of C. bishopi include works on comparative demography with C. alleganiensis (Peterson, 1985), food habits (Peterson et al., 1989a), fecundity and reproductive biology (Ingersol et al., 1991; Topping and Ingersol, 1981), winter breeding (Peterson et al., 1989b), nests and nest site selection (Nickerson and Tohulka, 1986), release of captive animals (Nickerson, 1980), and current management needs (Williams et al., 1981).

Recent purported declines in amphibian populations worldwide have prompted an increased awareness and concern regarding population trends in native United States species (Peckmann et al., 1991). Williams et al. (1981) reported that hellbender populations in the United States had undergone population declines throughout its range, although they also stated that large populations of C. bishopi were still present in the Spring River in Arkansas. Peterson (1985) confirmed the presence of these large aggregates while performing a mark and recapture on two populations in the Spring River from 1980 to 1982; he captured and tagged 370 animals. However, in recent years, reported sightings of C. bishopi have decreased dramatically.

The objectives of the present study were to determine the current population level of C. bishopi in the Spring River, assess the habitat use, and identify factors affecting the welfare of this species in Arkansas. Recommendations concerning the status of populations derived from this preliminary study are presented herein.

MATERIALS AND METHODS

Field Techniques.—A mark and recapture study began on 8 July 1991 and ended on 9 November 1991; 13 visits to 10 selected access sites along approximately 26 km of the Spring River in Fulton County, Arkansas (Fig. 1), were conducted. The source of the Spring River is Mammoth Spring which discharges 152 million gallons per hr. (Peterson, 1985) and maintains a temperature of 15 ± 2° for several km downstream. Scuba diving gear was donned in all but one collecting area. Salamanders were searched for by overturning rocks or by surveying open water habitats to 3.5 m in depth. Air and water temperatures as well as time of collection were recorded at each access site. Captured salamanders were permanently marked with Floy tags following the technique of Nickerson and Mays (1973b). Salamanders were not anesthetized prior to or during the tagging and mensural procedures, but were retained in five gallon containers of cold water. The total length and the snout-vent length of each animal were measured to the nearest mm on a standard fish board; mass (to the nearest g) was taken with a spring scale. Salamanders were also closely examined for external parasites or injuries. After photographing the animals, they were released at the approximate site of collection.
Only 20 hellbenders were observed (19 tagged) during the study which included 36 dive hrs. The following summarizes activities at the 10 Spring River access sites. Data compiled for salamanders are found in Appendix I.

**Access Site 1.** The U.S. Highway 63 access point is located approximately 0.46 km downstream from the springhead of Mammoth Spring. The site was visited on four separate occasions for a total of 10 dive hrs. Diving was conducted in an area starting at the spillway below dam #1 and continuing downstream for approximately 200 m. The habitat just below dam #1 consisted of vents which extended beneath the dam on both sides of the spillway. Small-to-medium sized rocks were present in the whitewater areas. No salamanders were found at dam #1. Warm Fork enters the Spring River just upstream from the U.S. Highway 63 bridge and approximately 100 m downstream from dam #1; the bottom open-water habitat in this area was mostly devoid of large rocks. No salamanders were observed in this area. Three salamanders, however, were observed (two tagged) on the downstream side of the U.S. Highway 63 bridge. The habitat here consisted of many loose as well as piled rocks; visibility at depths over 1 m was from 1-1.5 m. Water temperature during the dives in July averaged around 18°C.

**Access Site 2.** This access point is located approximately 1.4 km downstream from the springhead and is the same access point utilized by Peterson (1985; his site 2). An island divides the river into a deeper western flow and a very shallow eastern flow. Two dive hrs. were devoted to an area including the eastern flow and portions of the upper and lower western flow. Peterson (1985; his Table 8) indicated that 60 hellbenders were marked at this site. No salamanders were found at this site during the present study.

**Access Site 3.** This site can be observed from access site 2 and is approximately 0.4 km downstream from the island. Two dive hrs. were spent here. The river is fairly broad and shallow here and exhibits isolated large rocks and snags. No salamanders were observed.

**Access Site 4.** The Cold Springs access point is located approximately 3.6 km downstream from the springhead. The river is narrow and deep (>3 m) on either side of a bridge that crosses here. One dive hr. was spent here to investigate habitats beneath large vegetation mats in the river. No salamanders were found.

**Access Site 5.** This site, hereafter referred to as Dam Site #3, is located 5.6 km downstream from the springhead. The habitat searched included the spillway area below the dam (Fig. 2), a waste-water discharge area from the Spring River State Fish Hatchery (Arkansas Game & Fish Commission) situated at the anterior end of a large island, and portions of both the western flow and eastern flow around the posterior end of the island. Four dive hrs. were spent in these habitats; in addition, four hrs. were devoted to searching for hellbenders following a drawdown of the western flow at the dam (Fig. 2). With the assistance of Mr. Richard Shopen, an employee at the hatchery, the western flow was reduced to a minimum on 9 November 1991. This would allow the exposed mid-water habitats to be easily searched and would induce hellbenders to leave their shelters from beneath a wire-supported riprap area (Fig. 2B). A total of nine salamanders emerged from beneath the riprap in less than 30 min. following the drawdown; an additional two were taken from shallow rocky water several m away from the riprap. Although the spillway habitat had extensive cover, only these two salamanders were observed for the duration of the drawdown.

**Access Site 6.** This collection site is located less than 150 m downstream from the end of the large island at Access Site 5. Peterson (1985) collected and marked 310 animals at end of this large island (his site 1). From October 1985 to September 1986, Peterson et al. (1989a)
removed an additional 62 hellbenders from both of Peterson's original Spring River sites (1 and 2). Again, Peterson et al. (1990b) returned to collect in the Spring River on 31 January 1987, but they provided no data on the numbers of hellbenders collected on that day. A total of 5 dive hrs. was devoted on two occasions at this site during the present study. On 5 October 1991, the first dive at this site yielded six hellbenders; five of these were released untagged. The other animal was returned to the lab for observation. Three of its feet were totally missing, and the limb stumps appeared as open wounds (see Pfingsten, 1990). On 12 October 1991, the animal was tagged and released at the collection site. Further diving that day resulted in only five hellbenders (the same five as above?) being tagged. The river is very swift at this site and exhibits both a rocky as well as a solid bedrock substrate. In addition, this region of the river is heavily utilized by wading fishermen. The salamanders were discovered in the open and not under rocks.

Access Site 7.—This area, formally called Bayou Access by the Arkansas Game & Fish Commission, is located approximately 9.6 km downstream from the springhead. The site was visited once, but because of the heavy use by canoeists, no dives were attempted. However, two sightings of hellbenders were reported to me from riffle areas above and below this access point (see arrows on Fig. 1). One of the hellbenders was caught by a fisherman on 1 August 1991, and the other was spotted by a scuba diver in fall of 1991. Both reports are reliable ones.

Access Site 8.—The Many Islands access region of the Spring River is found approximately 18.3 km downstream from the spring headwaters. This region of the river is a common exit point for canoeists who use the Dam Site #3 as an entrance point. Downstream from this exit region are a group of small islands with many riffles and falls around them. Five dive hrs. were devoted to this downstream area with two hrs. considered as night dives. No salamanders were observed here during the present study; however, personnel of the Many Islands Canoe Rental services provided insight into the numbers of hellbenders that at one time were found in this area. One person observed large numbers of larvae at one falls (see arrow on Fig. 1) near an island, and the same person noted that sometime during the mid-1980's, commercial collectors took over 100 hellbenders in two days from the Many Islands area.

Access Site 9.—This access point, commonly referred to as the Myatt Creek access, is situated 20.3 km downstream from the springhead. Maximum water depth below fall areas was around 3 m. Four divers spent four dive hrs. within several stretches of the river, and no hellbenders were observed.

Access Site 10.—Camp Kiel access, located approximately 25 km downstream from the springhead, is the last easy access to the Spring River in Fulton County. A low-water bridge crosses the river at this point. Four dive hrs. (four divers) failed to find hellbenders at this site. The habitat above the bridge lacked large numbers of rocks and was relatively shallow throughout the area. No searching was conducted downstream from the bridge.

DISCUSSION AND RECOMMENDATIONS

The results of the present study indicate that populations of the Ozark hellbender, Cryptobranchus bishopi, within the upper reaches of the Spring River in Fulton County, Arkansas, are at very low densities compared to their numbers less than a decade ago. Putative reasons for this drastic decline are the removal of specimens for scientific or other purposes and habitat alteration related to extensive recreational activities (canoeing, fishing, swimming, etc.). Other contributing factors directly associated with human activity include the accidental killing of specimens by steering, swimming, and fishing practices. A spillage of diesel fuel directly into the river just below Access Site 4 following a train mishap (July, 1982) or a natural disaster (100 yr. flood of December, 1982) could have significantly reduced the numbers of salamanders (Richard Shopen, pers. comm.). Increasing the silt burden of the river due to the latest clearing of riparian habitats for farming/agricultural purposes, industrial uses, and human occupation and development poses an additional major threat. Water pollution from various sources has also created eutrophic conditions along the river. As stated ever so poignantly in a regional newspaper, the Spring River is being literally 'loved to death' (The Jonesboro Sun, 26 September 1991).

Field investigations are currently underway to attempt to locate additional populations of Ozark hellbenders in northern Arkansas in order to substantiate undocumented sightings (especially in the White River and its tributaries); yet, thus far, information from White River fishing and boating enthusiasts and four dive hrs. at Calico Rock and Red's Landing access point have failed to provide any confirmation that hellbender populations exist in the river.

The Spring River populations of C. bishopi may soon be unable to continue to survive and thrive under the present onslaught which threatens their critical habitat. Therefore, we propose that the Ozark hellbender in Arkansas be immediately placed on the state/federal list of threatened or endangered species.

ACKNOWLEDGMENT

This study could not have been completed without the ongoing assistance of several volunteers who gave their time and energy to the project. Scuba divers included, Matthew Dust (who provided underwater photographs), Susan and Dale Custer, and Keith Sharp. A special thanks goes to Richard Shopen, fish hatchery biologist for the Arkansas Game & Fish Commission, who secured keys and permission to enter various access points and who executed unflaggingly the drawdown at Dam Site #3. Bart Crisp and John Sawyer supplied information about hellbenders at the Bayou Access; Ed Tumbow assisted at the Many Islands access area; Rusty McAllister, Wei Chen, and Kim Hart provided additional field assistance. This study was funded, in part, by a research grant from the Arkansas Game & Fish Commission (Rex Roberg, Coordinator).

LITERATURE CITED


APPENDIX I
SPECIMENS EXAMINED

The following data were compiled for 19 hellbenders tagged during the present study and include in sequence [Date; Access Site; Tag #: Total Length (mm); Snout-vent Length (mm), and Mass (g)]; 8 July 1991, 1, 101, 500, 360, 950; 13 July 1991, 1, 104, 440, 310, 650; 12 October 1991: 6, 105, 460, 320, 600; 6, 108, 440, 270, 400; 6, 111, 310, 800; 6, 112, 515, 350, 1150; 6, 113, 540, 375, 1725; 6, 114, 525, 400, 2001; 9 November 1991: 5, 115, 565, 360, 1375; 5, 116, 580, 350, 900; 5, 117, (no additional data); 5, 118, 510, 360, 1125; 5, 119, 620, 400, 1350; 5, 120, 480, 350, 1125; 5, 125, 455, 310, 675; 5, 126, 460, 310, 700; 5, 127, 430, 280, 725; 5, 128, 430, 295, 650; 5, 129, 470, 310, 750; 5, 130, 460, 300, 750.
THE EFFECTS OF BACTERIAL LIPOPOLYSACCHARIDE ON PLASMA CORTICOSTERONE CONCENTRATIONS AND BODY TEMPERATURES OF NEW ZEALAND RABBITS (ORYCTOLAGUS CUNICULUS)

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ABSTRACT

Twelve New Zealand rabbits were injected with Salmonella typhosa endotoxin, 10 ng/kg b.w., via an auricular marginal vein and the effects of the pyrogen on the rectal temperatures and plasma corticosterone concentrations of these animals were observed.

Our data showed significant increases of the core temperatures from the normal 39.3 +/- 0.18 to 40.9 +/- 0.43 C (p < 0.001). Radioimunoassay results of the plasma corticosterone levels were 5.76 +/- 3.7 ug/100 ml in the pre-injection blood samples and 9.02 +/- 3.7 ug/100 ml in the plasmas obtained from the animals, one hour after the pyrogen was administered. The increase of corticosterone was significant (p < 0.05).

INTRODUCTION

Lipopolysaccharides or bacterial endotoxins are found to be useful to test the functions of the hypothalamic hypophyseal-adrenal axis. In such tests the pyrogenic substance is administered to laboratory animals or human subjects and concentrations of plasma corticotropin (ACTH) or glucocorticoid are measured. A correlation between endotoxin and cortisol was observed by Wolff (1973) who stated that this is a convenient way of testing the pituitary adrenal function.

Lipopolysaccharides are derived from the cell wall of gram negative bacteria. Commercial preparations have been produced from Escherichia coli, Pseudomonas aeruginosa, Salmonella abortis equi, Salmonella typhosa, and Pasteurella multocida. The minimum amount of the pyrogen that is required to induce fever and other types of biological responses in animals or humans varied according to the species or strain of the microbe from which the substance was derived. Wolff (1973) reported that rabbits required 5 ng/kg of endotoxin extracted from S. abortus equi compared to 50 ng/kg of the pyrogen obtained from S. typhosa. Elia et al., (1981) used a purified lipopolysaccharide prepared from E. coli 0113 which is the national reference bacterial endotoxin of the Bureau of Biologies of the Food and Drug Administration, Bethesda, Maryland. The rabbits in their study developed fever with 0.23 to 0.7 ng/kg doses of this product.

Several methods are proposed by investigators for quantitative measurements of the pituitary response to various stressful stimuli. However, a standardized test to measure this response is not available to date. Bacterial pyrogen is being used on the pituitary adrenal axis as a stressing agent. It is reported that both animals and human beings experience a rise in plasma corticosteroids when lipopolysaccharide is administered to them. (Melby et al., 1960; Farmer et al., 1961; Toth and Krueger, 1990). Methods of measuring plasma concentrations of glucocorticoid differ from laboratory to laboratory and the values obtained by these methods differ greatly. The plasma corticosterone in normal rats was measured by the competitive protein binding technique and fluorometry. The results of the two different methods were 4.3 +/- 0.8 and 8.0 +/- 0.8 ug/100 ml respectively, Stark et al., (1973/1974).

The purpose of this study was to determine the minimal pyrogenic dose of the S. typhosa endotoxin for the rabbits in our laboratory and to observe the effect of this minimal dose on the concentrations of plasma corticosterone measured by radioimmunoasay.

MATERIALS AND METHODS

New Zealand white rabbits, Oryctolagus cuniculus (Myrtle's Rabbit Farm, 4678 Bethesda Road, Thompson Station, Tennessee 37179) were used in this study. The animals were housed in individual cages in the air conditioned animal facilities at Arkansas State University. The room temperature was maintained at approximately 21.4 C. Purina rabbit chow and tap water were available ad libitum to the rabbits. These animals were acclimated to the housing conditions during a period of seven or ten days before the experiment was started.

At the beginning of the experiment, the rabbits were randomly separated into two groups, the controls and the experimental. The body weights of the animals were determined with a digital, small animal weight scale (Henry Schein, Co., 5 Harbor Park Drive, Fort Washington, New York 11050) and were recorded to the nearest gram. The rectal temperatures of these animals were measured with a Unisonic Digital Thermometer (1115 Broadway, New York, New York 10010) and were recorded to the nearest tenth of a degree Celsius.

As soon as the body weight and rectal temperature were recorded a 0.5 ml blood sample was collected from the middle auricular artery of each rabbit using a heparinized syringe fitted with a 1/2", 26G needle. The samples were transferred from the syringe to heparinized collection tubes, labeled and kept in ice during the collection period. These samples were centrifuged in a clinical centrifuge (IES Clinical Centrifuge, International Equipment Co., A Division of Damco, 300 Second Needham Heights, Maryland 02194) and the separated plasmas were transferred to labeled vials and stored at -10 C until assayed.

Following the blood collection the rabbits in the control group were given 0.9% NaCl in distilled water at the rate of 0.1 ml/kg b.w. via one of the marginal ear veins. The experimental rabbits were administered a solution of lipopolysaccharide (Sigma Chemical Co., P.O. Box 14508, St. Louis, Missouri 63178) which was at a concentration of 100 ng/ml in 0.9% saline. The rabbits required the pyrogen at 10 ng/kg b.w. in order to produce appreciable fever.

One hour after the injection the rectal temperature of each rabbit was recorded and approximately 0.5 ml of its blood was collected. The plasma was obtained and stored as previously described.

Corticosterone concentrations in the plasma samples were determined by radioimmunoasay. Chemicals for the assay were obtained from various sources as named: Labeled hormone, 1,2-3H-Corticosterone (New
The Effects of Bacterial Lipopolysaccharide on Plasma Corticosterone Concentrations and Body Temperatures

England Nuclear Corporation, 549 Albany Street, Boston, Massachusetts 02118; unlabeled corticosterone, bovine serum albumin - RIA grade Fraction V powder, and bovine gamma globulin (Sigma Chemical Company, P.O. Box 14508, St. Louis, Missouri 63178); corticosterone antiserum No. B3-163 (Endocrine Sciences Products, 18414 Oxnard Street, Tarzana, California 91356); boric acid - Certified A.C.S., ammonium sulfate - Certified A.C.S., toluene - HPLC grade, 2,5-Diphenyloxazole (PPO) - scintanalyzed, sodium chloride Certified A.C.S., sodium hydroxide - Certified A.C.S., and sodium azide - purified (Fisher Scientific Company, Fair Lawn, New Jersey 07410); as well as methanol - glass distilled (Burdick and Jackson Laboratories Inc., Muskegon, Michigan 49442).

All glassware used in this assay were soaked in alconox overnight, rinsed with tap water and immersed in 2 N nitric acid for a minimum of two hours. After a final rinse with distilled water they were dried in inverted positions in a clean oven at 60°C.

The reagents such as 10 N sodium hydroxide, 0.9% sodium chloride, saturated ammonium sulfate and 0.05 M boric acid of pH 8 were prepared in distilled water and these solutions were stored at room temperature in labeled bottles. A solution of bovine serum albumin (10%) was made with distilled water. The bovine gamma globulin (2.5%) was dissolved in the saline reagent. These protein solutions were prepared with 0.1% sodium azide and stored at 4°C. Unlabeled corticosterone was dissolved in redistilled ethanol to a concentration of 1 ug/ml, and the labeled hormone was dissolved with methanol to obtain 250 uc/ 5 ml. These preparations of the labeled and unlabeled corticosterones were stored at 4°C as stock solutions. The antiserum which was obtained as a dry powder was reconstituted with glass distilled water according to the supplier's specification. It was stored at -10°C. The scintillation fluid for this assay was mixed in the laboratory by adding 20 g of PPO to 4.1 of toluene containing 80 ml of glass distilled methanol.

The radiomiminoassay of corticosterone in the rabbit plasma, 50 ul of sample was mixed with 950 ul of borate buffer containing 0.25 % BSA and the mixture was placed in a water bath at 60°C for thirty minutes. After the incubation, 50 ul aliquots of the diluted sample were placed in duplicate assay tubes which were conical centrifuge tubes of 2 ml capacity. From each sample dilution that was included in an assay about 50 ul was collected in a test tube to be used as a pool of samples. This was used as an indicator of the nonspecific binders of the labeled corticosterone. Aliquots of pooled samples were placed in duplicate assay tubes as similarly as the samples.

One milliliter of the stock unlabeled corticosterone solution was evaporated to dryness in a vacuum oven at 40°C at a pressure setting of 25. The residue was redissolved in methanol and was diluted to construct a standard curve of 0, 0.125, 0.25, 0.5, 0.75, and 1.0 ng/0.1 ml in methanol. One hundred ul of these standards were placed in duplicate assay tubes and the methanol was evaporated in the vacuum oven as described.

A mixture of the antiserum and labeled corticosterone was made adequate for the assay by adding 20 ml of the borate buffer, 5 ul of the stock tritiated corticosterone, 0.4 ml of 10% BSA, 0.4 ml of 2.5% BGG and 0.4 ml of the stock antiserum solution. This mixture was aliquoted at 250 ul into each of the assay tubes containing the knowns and the unknowns. A similar mixture without the antiserum was prepared and it was added to the assay tubes containing the pooled plasma samples in order to detect the total amount of the nonspecific binders. The contents of the reaction vessels were thoroughly mixed in a vortex mixture and the tubes were placed in a water bath at 37°C for 45 minutes and at room temperature for the following 2 hours. The reactions were terminated by the addition of 250 ul of saturated ammonium sulfate per assay tube. The tubes were vortexed and were centrifuged at 3000 rpm for 10 minutes in a clinical centrifuge. Four hundred ul of the supernatant from each tube was transferred to a corresponding counting vial and 10 ml of the scintillation fluid was added. The radioactivities of the samples were determined by a LS-100, Beckman, liquid scintillation counter.

The standard curve was plotted as shown in Figure 1. The concentrations of the unknowns were extrapolated from the curve. In the assay the non-specific binding was about 15 percent. The sensitivity of the assay was about 12.5 ng/100 ml of plasma. Based on the available data, statistical inferences were derived by use of one-way analysis of variance or the student t-test. The body weights, rectal temperatures, and the plasma corticosterone concentrations of the control rabbits were compared to similar data obtained from the experimental animals. In addition, the matched pair t-test was performed to determine the significance of the differences between the pre-injection and the post-injection values of the rectal temperatures and of the plasma corticosterone levels in the experimental rabbits.

Figure 1. Corticosterone standard curve.

RESULTS AND DISCUSSION

Rabbits having body weights 1.5 to 4.3 kg were used in this study. The average body weights of the control group and the experimental group were similar (Table 1).

The rectal temperatures of the rabbits at the start of the experiment were 38.7 to 39.7°C. The mean rectal temperature of the control rabbits was similar to that of the experimental rabbits (Table 2).

Table 1. Body Weights of Rabbits.

<table>
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<th>Group of Animals</th>
<th>Number of Animals (N)</th>
<th>Body Weight (Kilogram) Mean +/- s.d</th>
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</thead>
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<tr>
<td>Controls</td>
<td>12</td>
<td>2.72 +/- 0.92</td>
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<tr>
<td>Experimental</td>
<td>12</td>
<td>2.79 +/- 0.92</td>
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Table 2. Rectal Temperature of the rabbits.

<table>
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<th>Groups of Animals</th>
<th>Number of Animals (N)</th>
<th>Rectal Temperature (Celsius) Pre-injection Post-injection mean +/- s.d.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Controls</td>
<td>12</td>
<td>39.1 +/- 0.25</td>
</tr>
<tr>
<td>Experimental</td>
<td>12</td>
<td>39.2 +/- 0.28</td>
</tr>
</tbody>
</table>
The rabbits given 0.9% NaCl injections showed no significant change of the mean rectal temperature one hour after the injection. The experimental rabbits received lipopolysaccharide at the rate of 10 ng/kg body weight and showed a significant rise of the rectal temperatures one hour post-injections (p < 0.001). The amount of pyrogen used in this study is larger than the amount of lipopolysaccharide administered by Elin et al., (1981) to their rabbits. They preferred smaller doses which were between 0.23 and 0.7 ng/kg body weight for the animals. The endotoxin used by these investigators was prepared from E. coli. It is the national reference bacterial endotoxin of the Bureau of Biologics of the Food and Drug Administration, Bethesda, Maryland. A similar preparation of the reference bacterial endotoxin was administered to rabbits by Dinarello et al., (1978) at the rate of 100 ng/kg and they reported that the rabbits consistently developed biphasic fever. Endotoxin derived from S. typhosa used by Wolff (1973) was not as potent as the pyrogen obtained from E. coli. Wolff's rabbits required this extract in doses as high as 50 ug/kg b.w., in order to develop fever. According to Greisman and Hornick (1969), the threshold pyrogenic dose of S. typhosa endotoxin was between 0.1 ng and 1.4 ng/kg b.w., that of E. coli endotoxin was about 1.0 ng/kg b.w. and that of Psuedomonas endotoxin was 50 to 70 ng/kg b.w. These data suggest that the endotoxic potency of lipopolysaccharides varies according to the species or strain of the microbes and the method of extraction.

Greener and Werner (1986) injected (0.1 ug/kg b.w.) S. typhosa endotoxin, a product which is similar to the pyrogen used in this study, into an ear vein in rabbits and observed core temperature increases in the rabbits. The fever in these rabbits was described as biphasic due to the occurrences of two peaks in the time lapse temperature graph. Greisman and Hornick (1969) had reported that small pyrogenic doses of endotoxin evoked febrile responses in rabbits, and the fever peaked at approximately 1.5 hours. Larger doses evoked a second peak attained within three hours. Atkins and Wood (1955a & b) recorded the features of the febrile response to typhoid vaccine by rabbits as (a) the short latem period (less than 10 minutes), (b) the abrupt monophasic response with a peak in 15-60 minutes and (c) the rapid defervescence to normal within 2 to 2.5 hours. The pyrogen that was used in this study at 10 ng/kg was sufficient to induce fever within an hour in the rabbits. The dose was insufficient to prolong the febrile state till three hours and to produce the second peak. The body temperatures of the rabbits in this study returned to normal within three hours.

The plasma corticosterone concentrations of the rabbits are presented in Table 3. The initial blood samples (pre-injection bloods) of the control rabbits and those of the experimental rabbits contained similar amounts of corticosterone. One hour after the administration of 0.9% saline the bloods of the control rabbits did not show marked changes in the amounts of the steroid. There were significant increases of corticosterone in the bloods of the experimental rabbits one hour after they received the lipopolysaccharide (p < 0.05).

Endotoxins of gram-negative bacteria when injected into man and animals are known to stimulate adrenal secretory activity. Administration of 0.25 ug of a lipopolysaccharide derived from S. abortus equi resulted in a two fold increase of plasma cortisol concentrations in 5 healthy humans (Melby et al., 1961). Farmer et al., (1961) found in humans that plasma cortisol concentrations increased from 16.4 ug to 44.2 ug per 100 ml in four hours when injected with 0.5 ug of Salmonella lipopolysaccharide. Carroll et al., (1969) observed a rise of 8 ug/100 ml above the base level of the cortisol in the plasma of human volunteers who received intravenous injections of Salmonella pyrogen.

Elis et al., (1981) observed in humans that the reference endotoxin when given in doses greater than 1 ng/kg b.w. interrupted the diurnal variations of serum cortisol and significantly elevated this steroid's levels. Melby et al., (1960) reported increased secretion of cortisol secretion in dogs which received a lethal dose of E. coli endotoxin intravenously. The increased secretary rate of the hormone in these animals was observed in a total of 30 minutes and 120 minutes after the administration of the pyrogen. Makove et al., (1971) observed circulating corticosterone rising from basal levels of 12 to 15 ug/100 ml to higher levels of 45 to 60 ug/100 ml in rats which were given E. coli endotoxin intraperitoneally. Toth and Krueger (1990) stated that cortisol increased in the bloods of these rabbits which were given P. multocida endotoxin. These findings are similar to the results of the present study.

CONCLUSIONS

The results of this study indicated that the rabbits in our laboratory required 10 ng/kg of S. typhosa lipopolysaccharide in order to produce a febrile response. Concomitant with the increase of body temperatures there were increases of the circulating amounts of corticosterone in the rabbits. The radioimmunoassay was deemed reliable because the hormone concentrations determined by this method, were in a wide range of 0.75 to 15.75 ug/100 ml.

ACKNOWLEDGMENT

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LITERATURE CITED


AN ASSESSMENT OF TIMBER RESOURCE VALUES IN ARKANSAS

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ABSTRACT

The Arkansas forest lands have long been and will continue to be an important contributor to the state's economy. Today, Arkansas forests cover 52 percent of the land area (Hines and Vissage, 1988). These forests are classified by physiographic characteristics into four timber regions. The timber removed from forested lands provides direct and indirect employment for approximately 40,000 people within the Arkansas manufacturing sector (Kluender and Willett, 1989). This paper describes county and region level information, identifies standing timber volumes, net annual timber growth, net annual timber removals, and associated dollar values. Timber stand data are used to determine areas suitable for new facilities or expanding existing wood-based manufacturing facilities. This study also identifies opportunities within each region for wood-based manufacturing growth.

INTRODUCTION

Arkansas is blessed with bountiful forest lands. These forests cover 52% of the total land area in Arkansas (Hines and Vissage, 1988). Arkansas' forests are customarily grouped into four regions based on physiographic characteristics. The regions include the Delta, Coastal Plain, Ouachita, and Ozark (Figure 1). The Delta region consists primarily of hardwood forests and covers 21 counties (Hines, 1988a). Twenty percent of the Delta region is forested. Hardwood forests cover 1.7 million acres while pine forests total 131 thousand acres. The Delta region's largest ownership group is non-industrial private forest landowners. The Coastal Plain region is heavily forested (73%). The dominant forest type is pine comprised of loblolly and shortleaf pines.

Figure 1. Arkansas' four timber regions classified by physiographic characteristics.

Pine forests total 1.5 million acres. Other Coastal Plain forest types include oak-pine (1.4 million acres), oak-hickory (1.4 million acres), and bottomland hardwoods (1 million acres). Forest industries own 50% of the Coastal Plain's forest lands (3.26 million acres). The twenty counties that make up the Coastal Plain have 6.44 million acres of forest lands (Hines, 1988). The Ouachita region covers only 10 counties, however the region is 65% forested. The primary forest types include oak-hickory and loblolly-shorleaf pine, covering 1.1 and 1.0 million acres, respectively. The USDA Forest Service is the largest forest landowner in the Ouachita region. National Forests account for 41% of the region's total forest land (Hines, 1988b). The fourth region, the Ozark region, is located in northwest Arkansas (Figure 1). Dominant forest types are oak-hickory (4.2 million acres) and loblolly-shorleaf pine a distant second (502 thousand acres) (Hines, 1988d).

The availability of wood volume is an important factor regarding additions or expansions to wood-based manufacturing facilities. The location of a wood-based manufacturing facility is a complex problem. Major considerations include adequate raw material supply, sufficient demand for the products produced, reasonable access to markets, labor in adequate supply, adequate capital funding and the ability to meet all governmental regulations applicable to operation of the firm (Kluender et al., 1991). This study is limited in scope to identifying the available raw material supply. Questions not considered include market information, owners willingness to sell their timber, and available employment.

Forest statistics necessary to determine the availability of wood volume start with the identification of growing stock volume and its stumpage value. Growing stock volume is the cubic-foot volume of sound wood in growing-stock trees at least 5.0 inches in diameter at breast height. The stumpage value is the dollar amount the market is willing to pay for standing wood volume. Growing stock volume alone does not reveal the presence of other wood-based manufacturing facilities and their demand upon the forest resources. Statistics necessary to capture the volume available for industry expansion include net-annual-growth of growing stock and net-annual-removals. Net-annual-growth is the average net annual volume increase for the inter-survey period (Hines and Vissage, 1988). Net-annual-removal is the average annual volume of growing stock trees removed from the inventory by harvesting, land clearing, or changes in land use. These two pieces of information lead to the calculation of growth to harvest ratios and finally, net-available wood volume. Growth-to-harvest ratios are calculated by dividing the net-annual-growth by net-annual-removals. If a growth-to-harvest ratio is greater than 1.0 to 1.0, then the forest is increasing in total volume. If a
growth-to-harvest ratio is less than 1.0 to 1.0, then harvests exceed net-
annual-growth. Harvests or removals in excess of net-annual-growth
deplete the growing stock. This is referred to as timber mining. Such
harvesting practices are not sustainable and work against long-term
economic development (Kluender et al., 1991). Net-available wood
volume is wood growth added annually to the growing stock volume, net
of removals. Throughout this paper the term “available” means annual
wood growth available in excess of annual harvest. All of these statistics
were necessary to the completion of the objectives of this study.

Two necessary conditions must be met for expansion of wood-based
manufacturing facilities. First, net-available volume must be available
in sufficient quantity and the correct species to meet the raw material
needs of the mill on a yearly basis. Second, the production over an
extended period of time, withdrawals from the forest (harvests) should be
such that growing stock volume will not be reduced once the mill is in
place. Accordingly, a growth to harvest level that will provide a
sufficient buffer for expected increased harvests must be selected to
identify potential mill locations. In most cases, a ratio of 1.2:1.0 should
be sufficient. This buffer will allow a mill to increase harvesting levels
without cutting into the growing stock volume if available volumes are
sufficiently high (Kluender et al., 1991).

Forest resource sufficiency is a measure of its ability to supply raw
material to wood-based manufacturing facilities. When timber harvest
levels are very near the level of annual timber growth (i.e., growth to
harvest ratios of 1.0:1.0), increased timber supplies must come from either:
a) forests in other states or countries, b) from the growing stock
volume, or c) additions to the annual timber growth through increased
plantings and management of existing timber stands (O’Laughlin and
Williams, 1988).

The objectives of this study were three-fold. The first objective was to
identify the growing stock volume and calculate the associated stumpage
value. The second objective was to identify net-annual-growth, net-
annual-removals, and calculate the growth to harvest ratio by county and
region. The third objective was to calculate the available wood volume by
county and region.

A concern in an aggregate analysis of this type lies with the forest
survey statistics, which are based on permanent plots located state-wide.
Sampling error ranges from a low of 1% to 2% to over 50% in some
counties, depending upon the number of plots assigned (Hines and
Vissage, 1988). As more plots are aggregated, sampling error decreases
for the area represented. Our opinions and comments reflect findings
from analyzing aggregate volumes, net-annual-growth and removals of
pine and hardwood tree species, subject to the errors described above.

METHODS

USDA Forest Service publications by Hines, (1988a,b,c,d) provided
the basic data analyzed for this study. Data analyzed included: growing-
stock volume of pine and hardwood trees, net-annual-growth and net-
annual-removals. Products by species group examined included pine
sawtumber, pine pulpwood, hard-hardwood sawtimber2, soft-hardwood
sawtimber3, and hardwood pulpwood. Growing stock volume published
in cubic foot volume was converted to board foot volume and cords. This
conversion was necessary to apply the stumpage values published by the
Cooperative Estimation Service (Geiser, 1992). Dollar values for
growing-stock volume were calculated from stumpage prices published in
growing-stock volumes were used to identify Arkansas’ existing total
forest volumes. Species groups were further divided into two product
classes (sawtimber and pulpwood). Sawtimber trees are live trees that
contain at least one 12-foot log, or two 8-foot logs in the saw-log portion.
Sawtimber volume is the volume of the saw-log portion of growing-stock
sawtimber trees. All growing-stock volume that did not meet saw-log
specifications was classified as pulpwood.

Once growing-stock volume was classified as either sawtimber or
pulpwood, market value was established based on stumpage prices from
the Forest Marketing Bulletin. The stumpage values used were $205 per
MBF Doyle scale for pine sawtimber, $18 per cord for pine pulpwood,
$120 per MBB Doyle scale for hard-hardwood sawtimber, $80 per MBB
Doyle scale for soft-hardwood sawtimber, and $8.50 per cord for
hardwood pulpwood (Geiser, 1992). Stumpage prices listed for pine and
hardwood species were multiplied by growing-stock volumes by product
class to calculate dollar values of standing live trees by county and
region. Net-annual-growth and net-annual-removals were used to
calculate growth to harvest ratios and net-available volume.

The determination of net-available volumes was the primary focus
of this paper. Net-available volume was calculated by subtracting net-
annual-removals from net-annual-growth. This study identified net-
available volume by species and product classification. Net-available
volumes were then converted to their appropriate dollar values by
multiplying volume by product class times the appropriate stumpage
value.

RESULTS AND DISCUSSION

GROWING STOCK VOLUME AND VALUE

Arkansas’ growing stock volume exceeds 64 billion board feet of
timber valued at $12 billion (Tables 1 and 2). This is enough wood to
pave a 24-foot wide boardwalk of 2 X 4s to the moon, circle it, and return

Table 1. Growing stock volume by species.

<table>
<thead>
<tr>
<th>Region</th>
<th>Pine Sawtimber MBB</th>
<th>Pine Pulpwood MBF</th>
<th>Hard Hardwood Sawtimber MBB</th>
<th>Hard Hardwood Pulpwood MBF</th>
<th>Soft Hardwood Sawtimber MBB</th>
<th>Soft Hardwood Pulpwood MBF</th>
</tr>
</thead>
<tbody>
<tr>
<td>COASTAL PLAIN</td>
<td>20,500</td>
<td>9,890</td>
<td>7,148</td>
<td>10,800</td>
<td>2,379</td>
<td>7,137</td>
</tr>
<tr>
<td>DELTA</td>
<td>619</td>
<td>626</td>
<td>1,371</td>
<td>4,576</td>
<td>3,211</td>
<td>2,329</td>
</tr>
<tr>
<td>OACACHITA</td>
<td>8,428</td>
<td>5,397</td>
<td>2,723</td>
<td>6,005</td>
<td>725</td>
<td>1,794</td>
</tr>
<tr>
<td>OZARK</td>
<td>2,845</td>
<td>2,697</td>
<td>8,550</td>
<td>20,015</td>
<td>1,585</td>
<td>2,589</td>
</tr>
<tr>
<td>TOTAL</td>
<td>32,452</td>
<td>18,609</td>
<td>20,342</td>
<td>41,101</td>
<td>8,900</td>
<td>14,828</td>
</tr>
</tbody>
</table>

Table 2. Growing stock timber value by species.

<table>
<thead>
<tr>
<th>Region</th>
<th>Pine Sawtimber Value (In Thousands of Dollars)</th>
<th>Hard Hardwood Sawtimber Value (In Thousands of Dollars)</th>
<th>Soft Hardwood Sawtimber Value (In Thousands of Dollars)</th>
</tr>
</thead>
<tbody>
<tr>
<td>COASTAL PLAIN</td>
<td>4,214,821</td>
<td>1,399,480</td>
<td>402,230</td>
</tr>
<tr>
<td>DELTA</td>
<td>17,272,022</td>
<td>2,605,296</td>
<td>5,800</td>
</tr>
<tr>
<td>OACACHITA</td>
<td>1,172,222</td>
<td>2,605,296</td>
<td>5,800</td>
</tr>
<tr>
<td>OZARK</td>
<td>583,225</td>
<td>1,414,932</td>
<td>126,880</td>
</tr>
<tr>
<td>TOTAL</td>
<td>6,562,404</td>
<td>4,013,432</td>
<td>538,713</td>
</tr>
</tbody>
</table>

to earth with another 24-foot walkway. Even with this huge volume of
wood growing in Arkansas’ forests, there is opportunity to increase wood
volume because 196 thousand acres (1%) of timberland are
bankrupted. An additional 4.2 million acres of timberland are sustainbiled.

Pine timber has a greater value of this state’s timber inventory at $7
billion or 58% of the total. The Coastal Plain Region of Arkansas has the
greatest percentage (63%) of pine sawtimber and (53%) pine pulpwood of
the four regions (Table 1). Pine sawtimber in the Coastal Plain region is
valued at $4.2 billion (Table 2). The total pine sawtimber value in the
state exceeds $6.6 billion. Additionally in the Coastal Plain, pine
pulpwood exceeds $344 million.

This state’s hard-hardwood sawtimber volume is concentrated in the
Ozark (36%) and the Coastal Plain (32%) regions. Hard-hardwood
sawtimber in Arkansas is valued at over $4 billion (Table 2). The Ozark
and the Coastal Plain regions have hard-hardwood growing stock
volumes valued at $1.4 and $1.3 billion, respectively.

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The Delta and Coastal Plain regions have 73% of the soft-hardwood growing stock volume (Table 1). The Delta region has 37% of the soft-hardwood sawtimber volume while the Coastal Plain region has 26%. Stumpage values are $264 and $262 million for the two regions, respectively.

Hard-hardwood pulpwood reserves are greatest in the Ozark region (47%) but soft-hardwood pulpwood is greatest in the Coastal Plain region (48%) (Table 1). Arkansas' hardwood pulpwood surpasses a value of $484 million (Table 2).

**GROWTH TO HARVEST RATIOS**

Figure 2 illustrates the growth to harvest ratios for all tree species and products combined. Pine timber is under heavy cutting pressure in much of the pine regions of Arkansas. The Coastal Plain and Ouachita regions have harvest to growth ratios less than 1.0:1.0 for pine species (Table 3). While several counties in these two regions have harvest to growth ratios greater than 1.0:1.0, the regions in aggregate have a growth to harvest ratio of less than 1.0:1.0. The Ozark and Delta regions have a growth to harvest ratio greater than 1.0:1.0 for pine species (Table 3). This is due largely because wood-based manufacturing facilities requiring pine timber have not been attracted to the low growing stock volumes of pine in these regions. The Ozark and Delta regions, under current harvesting levels, are adding pine volume to timber inventory.

![Figure 2. Growth to harvest ratios by countries combining all species and wood products.](image)

**Table 3. Growth to harvest ratios by tree species and forest regions.**

<table>
<thead>
<tr>
<th>Region</th>
<th>Pine</th>
<th>Hardwood</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coastal</td>
<td>.92</td>
<td>1.09</td>
</tr>
<tr>
<td>Delta</td>
<td>1.48</td>
<td>2.07</td>
</tr>
<tr>
<td>Ouachita</td>
<td>.67</td>
<td>1.77</td>
</tr>
<tr>
<td>Ozark</td>
<td>1.97</td>
<td>3.65</td>
</tr>
</tbody>
</table>

All four regions have growth to harvest ratios exceeding 1.0:1.0 for hardwood species. The Ozark region has a 3.65:1.0 growth to harvest ratio for hardwood species (Table 3). The Delta region's growth to harvest ratio for hardwood species is 2.1:1.0. Figure 2 emphasizes that aggregate growth to harvest ratios greater than 1.0:1.0 are found in the Ozark and Delta regions.

**NET-AVAILABLE VOLUME AND VALUE**

There is no net-available volume of pine sawtimber for new industries for the Coastal Plain and Ouachita regions, in aggregate (Table 4). However, a small four county area in the Coastal Plain region of southwest Arkansas produces an estimated $8 million annually in net-available pine sawtimber (Figure 3). Other groups of counties have net-available timber volume and growth to harvest ratios greater than 1.2:1.0. The availability of this resource would have been masked in the region-only analysis. The importance of county level data analysis and interpretation is confirmed.

![Figure 3. Value of available pine sawtimber in thousands of dollars at $200 per MBF Doyle scale.](image)

**Table 4. Net-available timber volume by species and region.**

<table>
<thead>
<tr>
<th>Region</th>
<th>Pine Sawtimber</th>
<th>Pulpwood</th>
<th>Polywood</th>
<th>Hard Hardwood</th>
<th>Pulpwood</th>
<th>Polywood</th>
<th>Soft Hardwood</th>
<th>Pulpwood</th>
<th>Polywood</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coastal Plain</td>
<td>20,506</td>
<td>2,600</td>
<td>7,768</td>
<td>10,264</td>
<td>3,279</td>
<td>4,210</td>
<td>5,175</td>
<td>4,210</td>
<td>5,175</td>
</tr>
<tr>
<td>Delta</td>
<td>619</td>
<td>626</td>
<td>3,175</td>
<td>4,270</td>
<td>3,210</td>
<td>2,290</td>
<td>7,194</td>
<td>2,290</td>
<td>7,194</td>
</tr>
<tr>
<td>Ouachita</td>
<td>8,428</td>
<td>1,297</td>
<td>6,201</td>
<td>4,210</td>
<td>775</td>
<td>5,175</td>
<td>3,210</td>
<td>5,175</td>
<td>3,210</td>
</tr>
<tr>
<td>Ozark</td>
<td>2,849</td>
<td>2,497</td>
<td>8,555</td>
<td>30,315</td>
<td>1,584</td>
<td>3,210</td>
<td>3,210</td>
<td>3,210</td>
<td>3,210</td>
</tr>
<tr>
<td>TOTAL</td>
<td>32,452</td>
<td>15,000</td>
<td>32,762</td>
<td>45,520</td>
<td>8,900</td>
<td>14,818</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The Ozark region has 77 million board feet of available pine sawtimber valued at $14 million annually (Table 4). The Delta region has 6 million board feet of available pine sawtimber annually. Net-available pine sawtimber for new or expanding wood-based manufacturing facilities is limited.

By our selection criteria of positive net-available volume in the presence of growth to harvest ratios exceeding 1.2:1.0, there is no available pine pulpwood in the Delta, Ouachita, and Ozark regions. Some individual counties do have growth to harvest ratios greater than 1.2:1.0, but the region level analysis masks these areas. The Coastal Plain region has a small volume available totaling 75 thousand cords (Table 4). Two
areas of net-available pine pulpwood were identified within the Coastal Plain region. The first area contains Calhoun, Ashley, Bradley, Cleveland, and Dallas counties. The second area is Columbia and Lafayette counties. Localized studies are recommended to determine if the net-available pine pulpwood could sustain increased harvests due to wood-based manufacturing facilities or new plants.

Hard-hardwood sawtimber is available in all four regions (Table 4). However, the Ozark region has the largest concentration of net-available hardwood sawtimber valued at $44 million (Table 5). Four counties have growth value exceeding $3 million, for a total of over $12 million annually. These counties include Madison, Marion, Newton, and Searcy in extreme north central Arkansas. Additionally, five adjacent counties have annual growth valued at $2 million and five counties have growth valued at $1 million per year. The total annual hard-hardwood timber available from these fourteen counties exceeds $27 million per year (Figure 4). The total net-available hard-hardwood timber in the state is 639 million board feet annually (Table 4) valued at $76 million annually (Table 5).

Net-available soft-hardwood sawtimber totals 189 million board feet (Table 4) and is valued at $15 million per year (Table 5). All four regions have net-available soft-hardwood sawtimber. The Delta region has the greatest volume of soft-hardwood sawtimber with 77 million board feet valued at over $6 million per year. A close second is the Ozark region with 64 million board feet worth $5 million per year. There is no hardwood pulpwood available in the Coastal Plain region (Table 4) based upon net-available volume and growth to harvest ratios exceeding 1.2:1:1.0. The region level analysis masks areas within the Coastal Plain region where hardwood pulpwood has net-available volumes..

The greatest volume of available hardwood pulpwood is in the Ozark region. This region has 537 thousand cords per year (Table 4) of net-available hardwood pulpwood valued at $5 million annually (Table 5). The Delta region produces 106 million cords of net-available hardwood pulpwood per year.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>COASTAL PLAIN</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DELTA</td>
<td>1,540</td>
<td>0</td>
<td>13,464</td>
<td>4,128</td>
<td>17,592</td>
</tr>
<tr>
<td>OUACHITA</td>
<td>0</td>
<td>0</td>
<td>5,916</td>
<td>1,776</td>
<td>7,692</td>
</tr>
<tr>
<td>OZARK</td>
<td>14,780</td>
<td>0</td>
<td>44,124</td>
<td>5,152</td>
<td>54,272</td>
</tr>
<tr>
<td>TOTAL</td>
<td>16,220</td>
<td>1,540</td>
<td>76,656</td>
<td>15,088</td>
<td>91,744</td>
</tr>
</tbody>
</table>

Figure 4. Value of available hard-hardwood sawtimber in thousands of dollars at $120 per MBF Doyle scale.

The present availability and growth to harvest ratios of pine pulpwood prohibits any expansions of wood-based manufacturing using pine pulpwood on a regional level. Some counties within each region were found to have available pine pulpwood volume. The available pine pulpwood should increase in the Coastal Plain region as rapidly growing pine plantations begin reaching maturity.

**HARD-HARDWOOD SAWTIMBER**

All four regions within the state have net-available hard-hardwood sawtimber. The area with the largest potential for expansion of wood-based facilities using this resource is in the Ozark region. This region has 57% of the net-available hard-hardwood sawtimber.

**SOFT-HARDWOOD SAWTIMBER**

Arkansas’s four timber regions all have net-available soft-hardwood timber. The area of greatest net-available volume (77 million board feet, a value of $6 million per year) is in the Delta region. Desha county in the Delta region has the only available soft-hardwood volume exceeding $1 million in value annually. The surrounding counties of Arkansas and Chicot contribute another $1 million in annual soft-hardwood sawtimber growth.

**HARDWOOD PULPWOOD**

Available hardwood pulpwood abounds in the Delta and Ozark regions of Arkansas. These two regions have over $6 million per year of net-available hardwood pulpwood. These two regions could sustain expansion of wood-based manufacturing facilities requiring hardwood pulpwood.

**CONCLUSION**

This study has focused on forest resource availability. Areas that could possibly support expansion of wood-based manufacturing facilities have been identified. The location of new or expansion of existing wood-based manufacturing facilities should proceed with a more detailed analysis of species available, the presence of purchasable timber, and available labor supply. Additional study could provide the information not considered in this analysis.
LITERATURE CITED


PROCEEDINGS

BIOLOGICAL VECTORS FOR DISPERAL OF
COLLETOTRICHUM GLOEOSPORIOIDES

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ABSTRACT

Green treefrogs (Hyla cinerea) and grasshoppers (Melanoplus differentialis and Conocephalus fasciatus) commonly observed in Arkansas rice fields, are dispersal vectors for Colletotrichum gloeosporioides f. sp. aeschynomenae, a causal agent of anthracnose of northern jointvetch. Treefrogs and grasshoppers captured from rice or soybean fields with diseased northern jointvetch plants were placed in containers in contact with healthy northern jointvetch plants. An average of 90% of northern jointvetch plants was infected by the pathogen with up to 10 lesions per plant using treefrog vectors. Experiments were done in the greenhouse on frog dispersal by monitoring disease development from a point source in closed rice-weed patches. Treefrogs dispersed the pathogen from the source plant to healthy plants resulting in 95% infection. In the field, grasshoppers were frequently observed feeding on anthracnose lesions. In six separate experiments, approximately 20% of grasshoppers collected from fields with diseased northern jointvetch transferred the disease after feeding or contacting healthy plants. By feeding pathogen-free grasshoppers on anthracnose lesions, we found that 66% of these grasshoppers transferred the disease to healthy plants. The grasshopper may be important in spreading the inoculum among weed patches. Green treefrogs appear to be efficient vectors of the disease because they preferred northern jointvetch plants as shelters.

INTRODUCTION

Colletotrichum gloeosporioides f. sp. aeschynomenae (Penz) (CGA) incites an anthracnose of northern jointvetch (Aeschynomene viridica B.S.P.), a tall leguminous weed of rice and soybean fields in the Mississippi River Delta region. Colleto, a commercially used mycoherbicide, was developed using this fungal pathogen. The ecology of this pathogen has been extensively studied as a model system for Colletotrichum species. Information on dispersal mechanisms for this pathogen is limited to physical vectors such as rain-splash studies (Templeton et al., 1979; Yang and TeBeest, 1991). Because species of Colletotrichum are important agents in weed biocontrol (TeBeest, 1990), understanding the dispersal of this fungus is important for development of mycoherbicides. Field observations suggest that the dispersal complex of CGA in rice fields consists of both physical and biological components. Grasshoppers have been observed feeding on anthracnose lesions of diseased northern jointvetch plants. A hypothesis that grasshoppers may be a vector of the pathogen was made as early as the 1970's (Templeton et al., 1979) but has not been tested experimentally. Green treefrogs (Hyla cinerea Schneider) are commonly observed in rice and soybean fields in the south, however, little is known about the role of amphibians spreading fungal pathogens, and no studies of pathogen dispersal by frogs were found. The objectives of this study were to determine if grasshoppers and green treefrogs can act as dispersal vectors of CGA and to determine the importance of these vectors to the development of disease epidemics in northern jointvetch.

MATERIALS AND METHODS

TREEFROG TRANSMISSION.

Frogs were captured near Stuttgart, Arkansas on four separate occasions during the 1991 rice growing season from 10 different rice fields infested with diseased northern jointvetch plants. In the first sampling, 15 and 18 frogs were caught from two patches of northern jointvetch. Twelve frogs per patch were caught for the second and third samplings. The fourth sampling was taken during the harvesting season from two rice fields. One of the two sampled fields did not contain northern jointvetch but was adjacent to a field infested with diseased northern jointvetch plants. In the field without northern jointvetch, the green treefrogs were captured from rice plants. Treefrogs from each sampling were returned to the laboratory in Fayetteville, AR in plastic bags or plastic bottles on the same day. Each patch was considered as a sampling unit and all treefrogs from one patch were bulked as one sample.

In the laboratory, treefrogs from each patch were placed in glass containers 45 cm high x 22 cm diameter or plastic containers 45 cm high x 35 cm diameter for 24 hr. Each container had three or four pots of healthy northern jointvetch plants approximately 40 cm tall. The number of plants per container varied for different experiments (Table 1). After 24 hr, frogs were removed and plants were placed in a dark dew chamber at 28 C for 24 hr. A control treatment in which plants were not placed in contact with treefrogs was included for each test. After incubating inoculated plants in growth chambers at 28 C for 5 days, the number of infected plants and number of lesions/plant were determined for each sampling unit.

To determine if frogs vectored the inoculum of C. gloeosporioides f. sp. aeschynomenae from plant to plant, simulated rice-weed patches were assembled in a greenhouse. Each patch was enclosed with screen in a frame 122 x 81 x 100 cm with the bottom of each frame containing a water reservoir 2 cm deep with a surface area of 76 x 115 cm. Twenty-
four rice plants at heading stage were transplanted into each frame. The average number of tillers per rice plant was 14 and there were 336 rice tillers per patch. Ten healthy northern jointvetch plants taller than the rice plants were evenly distributed in each rice patch and a diseased northern jointvetch plant with 5 to 7 anthracnose lesions was placed at the center. Three treatments, each with 2 replicates, consisting of 10 frogs/patch, 2 frogs/patch, and 0 frogs/patch were established. Test frogs were placed in a dew chamber at 28 C for 24 hr prior to their use, to rid them of residual spores. Temperature in the greenhouse was maintained at 25 C and free moisture was provided every two days using humidifiers and by covering the frame with plastic sheeting. Treefrogs were fed commercial diet every two days. The number of diseased plants, killed plants, and lesions/plant was counted twice for each patch during the test.

To quantify green treefrog movement and shelter selection, the number of frogs sitting on the 336 rice tillers, on the 10 northern jointvetch plants, or on the screen of the frame were counted two to four times per day from 8 AM to 8 PM only in the 10 frog/patch treatment. A total of 56 observations was recorded. These observations were then averaged by counting the number of treefrogs on rice or on northern jointvetch plants and plotting these against time.

GRASSHOPPER TRANSMISSION.

Two different experiments were performed to determine grasshopper transmission. The first experiment was to determine if the pathogen was carried by grasshoppers in rice or soybean fields infected with diseased northern jointvetch plants. From the previously mentioned commercial rice or soybean fields, shorthorn (Melanoplus differentialis) and longhorn (Neononoceratophus crassipes and Conocephalus fasciatus) grasshoppers were captured with an insect net during the growing season. Grasshoppers were returned to the lab the same day and each grasshopper was placed for 24 hr in a test chamber constructed of a transparent plastic bottle (10 cm in diameter and 22 cm in height) containing a healthy northern jointvetch plant approximately 3 weeks old. Chambers were then placed under a light bench or in a growth chamber for 24 hr. Five insect-free test chambers were used as controls. The plants were next moved into a dew chamber at 28 C for 24 hr to induce infection and then kept in a growth chamber at 28 C for four days. Lesions on each test plant were counted and grasshopper feeding marks were also noted. The experiment was repeated seven times during the growing season. Grasshopper sampling size at each replication varied, depending on the moisture condition on the sampling day. In the second experiment, grasshoppers were caught from the Fayetteville area of northwestern Arkansas where northern jointvetch and the disease has not been reported to occur. Grasshoppers were fed wheat seedlings for one to two days before each test. Each grasshopper was put into a glass tube (4 cm in diameter and 30 cm in height) containing a 2 cm stem segment of northern jointvetch bearing a lesion caused by CGA. After insects were exposed to the lesion for 24 hr, each grasshopper was moved into a test chamber as described above. Healthy plants then received the same treatments as the first experiment. Numbers of infected plants and lesions per plant were recorded. Two control treatments were set up for each replicate. In the first control treatment, ten (10) healthy northern jointvetch plants were treated only with 24 hr dew. In the second control treatment, ten healthy plants were placed in contact with insects which had been fed on healthy stem segments, the plants were then provided 24 hr dew at 28 C. The experiment was repeated two times.

RESULT

TREEFROG TRANSMISSION.

In four separate experiments, healthy northern jointvetch plants were infected by C. gloeosporioides f. sp. aescynomenae after coming in contact with frogs collected from 16 diseased northern jointvetch patches in 10 different rice fields (Table 1). Percentages of plants infected after contact with frogs ranged from 25 to 100%, with greater than 90% infection for most patches. No infection of control plants was observed in the two tests. The number of lesions/plant ranged from 1 to 10. Plants placed in contact with frogs sampled from a field without northern jointvetch plants in October were also infected.

C. gloeosporioides f. sp. aescynomenae was dispersed among healthy plants by treefrogs in the simulated rice-weed patch experiment after the introduction of diseased northern jointvetch (Table 2). New disease lesions were observed during the first experiment six days after diseased plants were introduced. In the second experiment, infected plants were observed eight days after the introduction of source plants. An average of 95% plants were infected within sixteen days of the introduction of source plants. An average of 4.5 and 5.5 northern jointvetch plants were killed in the first and second experiments for the 10-frog treatment. There were noticeable differences in lesion/plant between 2-frog and 10-frog treatments. No infected plants were observed in the treatment without frogs.

Table 2. Results of dispersal experiments of Collectotrichum gloeosporioides f. sp. aescynomenae by green treefrogs (Hyla cinerea) in simulated rice-weed patches, as indicated by the number of diseased northern jointvetch plants.

<table>
<thead>
<tr>
<th>Frogs/patch</th>
<th>1st observation</th>
<th>2nd observation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Plnts infected</td>
<td>Plnts killed</td>
</tr>
<tr>
<td>0 frog</td>
<td>0.0 ± 0.0</td>
<td>0.0 ± 0.0</td>
</tr>
<tr>
<td>2 frogs</td>
<td>2.0 ± 1.4</td>
<td>1.0 ± 0.5</td>
</tr>
<tr>
<td>10 frogs</td>
<td>8.0 ± 2.0</td>
<td>4.0 ± 1.5</td>
</tr>
</tbody>
</table>

"Time of first and second observations was 8 and 16 days after introduction of source inoculum for experiment 1, and 10 and 28 days for experiment 2.
Mean values and standard error.

Green treefrogs were observed in rice fields in May when rice was planted. In the middle of the growing season, after the rice flowered and northern jointvetch plants were taller than rice, large numbers of treefrogs were observed. Treefrogs were often observed on the upper parts of northern jointvetch on clear days; however, during the early morning or on windy days, treefrogs were more frequently observed on lower parts of northern jointvetch plants beneath the rice canopy. Treefrogs were frequently observed sitting on anthracnose lesions on northern jointvetch plants above or inside the rice canopy (Fig. 1), especially later in the growing season when disease incidence was high.

Figure 1. A green treefrog (Hyla cinerea) sitting on an anthracnose lesion caused by Collectotrichum gloeosporioides f. sp. aescynomenae on a stem of northern jointvetch in a rice field.
The behavior of treefrogs in simulated rice-weed patches in a greenhouse appeared consistent with field observations. Frogs usually sat motionless on upper parts of northern jointvetch plants with their abdomens firmly in contact with the plant stem and appeared to prefer northern jointvetch plants as shelters with more than 80% of frogs observed on the northern jointvetch plants as compared to rice (Fig. 2). Most disease lesions were found on the upper portions of the stems.

![Graph](image)

**Figure 2.** Results of shelter selection by green treefrogs (*Hyla cinerea*) in simulated rice-weed patches. Numbers of green treefrogs (*Hyla cinerea*) sitting on 336 rice tillers or on 10 northern jointvetch plants during day hours in simulated rice-weed patches.

GRASSHOPPER TRANSMISSION.

In rice fields, wounds caused by grasshoppers were frequently observed on northern jointvetch plants around the anthracnose lesions. In the first two experiments, approximately 10 *Neocnemophora crepans*; the longhorn grasshopper, were tested, but the insects did not feed on northern jointvetch stems. This grasshopper species was not used in later experiments. Grasshoppers transmitting *C. gloeosporioides* in these experiments were the longhorn meadow grasshopper (*Coneophthalmus fasciatus*) and the differential grasshopper (*Melanoplus diferentialia*) which fed on northern jointvetch. Lesions appeared within the wound area of a stem three to four days after insect wounding. Occasionally, lesions were observed on part of a stem where no insect feeding wounds were noted. Among the five experiments in which grasshoppers were collected from rice, there was an increasing trend of disease with an average incidence of 22%. For the last experiment, a high incidence of 40% was found using grasshoppers obtained from one soybean field. In the experiment where grasshoppers acquired the inoculum by feeding on lesions, the average incidence was 70%.

**DISCUSSION**

Our studies revealed that both grasshoppers and green treefrogs are potentially important dispersal vectors of *C. gloeosporioides* f. *sp. aeschynomene* in rice fields. These vectors transfer a considerable amount of inoculum based on infection results (Tables 1 and 3). Treefrogs moved the pathogen from plant to plant (Table 2) and preferred northern jointvetch plants to rice as shelters. This is the first report of frogs as a vector of plant fungal pathogens.

Insects have been found to be major vectors in some plant pathosystems. However, the significance of grasshoppers in the studied pathosystem is not clear. Several factors may influence the importance of grasshoppers. Grasshopper populations vary from year to year, resulting in the variation of vector numbers. Importance is also determined by preference of grasshoppers to feed on disease lesions compared to healthy plant areas. If there is no preference, the chance of grasshoppers acquiring the inoculum will be a linear function of disease incidence. On the other hand, if grasshoppers actively search for disease lesions, potential significance of this vector would be much greater. A future study of feeding preferences of the various species of grasshoppers toward diseased and healthy tissue is needed.

Green treefrogs may be efficient vectors in this pathosystem because of their behavior. Ecological studies (Dullum, 1986; Mantis, 1987; Wright and Wright, 1942) as well as the present data indicate that treefrogs prefer tall plants as shelters. This behavior prevents attacks from snakes and fish (Garton and Brandon, 1975; Wright and Wright, 1942) and provides better vision for predation (Freed, 1980). Northern jointvetch is one of several taller weeds in rice, and an infested rice field can be dominated by this weed. Because green treefrogs selectively seek northern jointvetch as shelters, the density of the frogs/m² may be concentrated in the weed patch compared to other parts of a rice field. In the weed patch, the chance of moving the inoculum from a diseased plant to a neighboring healthy plant is very high and should result in target-specific horizontal movement of inocula. It has been observed that disease lesions on northern jointvetch plants in rice fields are in positions taller than rice. This may be because of frog movement and because the upper parts of plants are more susceptible. In the field, direct contact with lesions may not be necessary for treefrogs to obtain fungal inoculum. Because CGA produces large numbers of conidia (Templeton et al, 1979), large areas of the lower stem can become contaminated when rain washes these spores down from upper lesions. As the treefrogs move up and down the plants, the chance of acquiring the inoculum increases. Furthermore, vertical movement of grasshoppers in rice in our study as well as others (Dullum and Trube, 1986) provides a means of vertical dispersal moving inocula from lower to upper plant parts if the initial infection by seedborne (TeBeest et al, 1992) or rain-splash inoculum (Yang and TeBeest, 1991) occurs at the base of the plant.

The finding that grasshoppers and treefrogs transmit *C. gloeosporioides* f. *sp. aeschynomene* suggests a role of biological vectors in the formation of spatial patterns of plant diseases. Because northern jointvetch is distributed as patches in rice (Yang unpublished), rain dispersal is not as likely to move the pathogen from one patch to another because the maximum dispersal distance in rice is only 1.5 m in a single rain episode (Yang and TeBeest, 1991). However, grasshoppers are capable of flying from patch to patch, and it is known that frogs migrate as far as several hundred meters during reproduction or when food is scarce (Dullum and Trube, 1986). Such long distance movement of these vectors may provide a dispersal mechanism from patch to patch.

Grasshoppers and treefrogs may be important factors to consider in biological risk assessment of mycoherbicides. Many species of *Colletotrichum* have been studied as potential mycoherbicides and genetic-engineering techniques are being investigated to enhance their efficacy (TeBeest, 1990). Eventually these engineered organisms will be subjected to field tests, and the presence of these vectors in test plots may increase the chances of unwanted dispersal. The distance of grasshopper movement is far greater than other physical dispersal mechanisms, which increases the risk level. Furthermore, shelter selection by treefrogs can

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### Table 3. Infections of plants facilitated by either grasshoppers fed with diseased lesions or grasshoppers from rice fields inoculated with northern jointvetch infected by *Colletotrichum gloeosporioides f. sp. aeschynomene*.

<table>
<thead>
<tr>
<th>Test</th>
<th>Field</th>
<th>Grasshoppers tested</th>
<th>Infected plants (%)</th>
<th>Lesions/plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>From field</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21/07</td>
<td>TeBeest</td>
<td>20</td>
<td>15</td>
<td>1</td>
</tr>
<tr>
<td>31/07</td>
<td>TeBeest</td>
<td>27</td>
<td>20</td>
<td>1</td>
</tr>
<tr>
<td>14/08</td>
<td>TeBeest</td>
<td>12</td>
<td>17</td>
<td>1</td>
</tr>
<tr>
<td>28/08</td>
<td>TeBeest</td>
<td>4</td>
<td>25</td>
<td>1</td>
</tr>
<tr>
<td>06/09</td>
<td>Yang</td>
<td>9</td>
<td>33</td>
<td>1.3</td>
</tr>
<tr>
<td>27/09</td>
<td>Soybean 1</td>
<td>7</td>
<td>14</td>
<td>1</td>
</tr>
<tr>
<td>27/09</td>
<td>Soybean 2</td>
<td>9</td>
<td>11</td>
<td>1</td>
</tr>
<tr>
<td>27/09</td>
<td>Soybean 3</td>
<td>10</td>
<td>40</td>
<td>1</td>
</tr>
<tr>
<td>Lab test</td>
<td>test 1</td>
<td>20</td>
<td>66</td>
<td>3.6</td>
</tr>
<tr>
<td>Lab test</td>
<td>test 2</td>
<td>16</td>
<td>79</td>
<td>3.8</td>
</tr>
</tbody>
</table>
direct the movement of pathogens, and may increase the chance of gene exchange between different fungi. For example, mating has been observed between strains of *C. gloeosporioides* f. sp. *aeschynomene* and *C. aloeosporioides* f. sp. *jussiaeae*, two related fungi infecting northern jointvetch and winged water primrose, respectively (TeBeest *et al.* unpublished). These two plants are both tall weeds in rice fields and are favorite shelters for treefrogs. The fact that these two weeds are frog shelters may greatly increase the chance of contact and gene exchange between the above pathogens.

ACKNOWLEDGMENT

We thank Dr. R.J. Smith Jr. for assistance and Drs. R. Cartwright and C. Cisar for reviewing the manuscript.

LITERATURE CITED


DISTRIBUTION OF THE SOUTHERN RED-BACKED SALAMANDER, PLETHODON SERRATUS (CAUDATA: PLETHODONTIDAE), IN THE OUACHITA MOUNTAIN REGION OF ARKANSAS

The southern red-backed salamander, *Plethodon serratus*, is a plethodontid salamander characterized by a high number of costal grooves (18-20), a long slender body, and a pronounced mental gland under the chin. This gland is prominent on the chins of sexually active males and is shell-like in contrast to the oval shaped gland of the zigzag salamander, *Plethodon dorsalis* (Behler and King, The Audubon Society field guide to North American reptiles and amphibians (A.A. Knopf, publisher), Chanticleer Press, p. 347, 1987). *Plethodon serratus* is typically found under rocks, stones, logs and forest floor litter, in relatively mesic conditions, in the southeastern United States.

The *P. serratus* in Arkansas represent one of five disjunct populations for the species (Conant and Collins, A field guide to reptiles and amphibians of eastern and central North America, Moughton Mifflin. 450 pp., 1991) and is distinguished from *P. dorsalis* by range, with the Arkansas River Valley separating the species. The known records probably represent the western most margin of their distribution. Although there are remaining gaps in the known range, we found *P. serratus* to be locally abundant and will eventually be shown to occur throughout the remainder of the Ouachita mountain region of Arkansas.

This study was undertaken to amass past and present distribution patterns in order to suggest a current distribution map (Fig. 1) for the species, in Arkansas. The distribution presented reveals a broad range that extends eastward from the Oklahoma-Arkansas state line to Garland county and from Logan county southward to Pike, Clark, and Howard counties.

![Map of Arkansas showing distribution of *Plethodon serratus*.](image)

**Figure 1.** Known localities (solid circles) for *Plethodon serratus* in Arkansas. OZNF = Ozark National Forest; OUNF = Ouachita National Forest.

Distributional data were derived from *P. serratus* sampled during recent ground searches and road cruising activities. These were collated with historical distribution records taken from museums at Arkansas State University, Michigan State University, University of Oklahoma, Northwest State University of Louisiana, University of Arkansas at Monticello, Northeast Louisiana University, Louisiana State University at Shreveport, Southwest Missouri State, Mississippi State, Carnegie Museum, Milwaukee Public Museum, University of Missouri at Columbia and the U.S. National Museum of Natural History. Over 932 voucher specimens are included in this study 1951 to present.

*Plethodon serratus* has been documented from Logan, Yell, Polk, Montgomery, Garland, Howard, Pike, Clark and Scott counties. The Scott county location represents a new county record for *P. serratus* (Dowling, H.G. 1957. A review of the amphibians and reptiles of Arkansas. Occ. Pap. Univ. Arkansas Mus. 3:1-51). Perry, Saline and Hot Spring counties were sampled but have yet to reveal *P. serratus*. In summary, we conclude that *P. serratus* is locally abundant and widespread throughout the Ouachita Mountain region of Arkansas.

**ACKNOWLEDGMENT**

We thank Earl Stewart (U.S. Forest Service), and Jim Stewart (U.S. Fish and Wildlife Service) for assistance during field collections.

M. DOUG FLETCHER, 320 S.E. 3rd Street, England, AR 72046, BETTY G. COCHRAN, U.S. Forest Service, Ouachita National Forest, Glenwood, AR 71943, STANLEY E. TRAUTH, Department of Biological Sciences, Arkansas State University, State University, AR 72467, DAVID A. SAUGEY, U.S. Forest Service, Ouachita National Forest, Jessieville, AR 71949.
A SYNOPSIS OF THE GENUS TROPISTERNUS (COLEOPTERA: HYDROPHILIDAE) IN ARKANSAS

Information about Tropisternus species in Arkansas is restricted to listings in faunal surveys (e.g. Harp and Harp, 1980; Huggins and Harp, 1983; Cochran and Harp, 1990). Further, little has been written about preferred habitat for individual species (Spangler, 1960). The purposes of this study are to present a statewide list, to describe geographic distributions and to report preferred habitats for the water scavenger beetles of this genus, to the extent that current knowledge will allow. Arkansas species may be identified by using Spangler’s (1960) keys.

This study has utilized specimens provided by those sources listed in Acknowledgments, literature records, and collections by the authors and students at Arkansas State University. The latter specimens are preserved in 70% ethanol and housed in the Aquatic Macrionvertebrate Collection of the Arkansas State University Museum of Zoology. Over 4,200 specimens have been analyzed.

Figure 1. T. l. nimbatus.

Figure 2. T. c. striolatus.

Figure 3. T. c. mexicanus.

Figure 4. T. b. blatchleyi ●

T. b. modestus ▲

Figure 5. T. natactor

Figure 6. T. glaber ▲

T. ellipticus ●

Tropisternus lateralis nimbatus (Say) occurs from Nova Scotia to southern British Columbia, then south through Mexico to Panama, and through West Indies to Barbados (Spangler, 1960). It is predictably Arkansas’ most common form. We have collected it in all six Natural Divisions (ecoregions), as defined by Shepherd (1984). It is known by 3,176 specimens in over 500 collections from 64 counties (Fig. 1). It occurs in a variety of aquatic habitats, including mineral acid lakes (Harp and Hubbard, 1972), acid bogs (Parris and Harp, 1982), sewage lagoons, springs and temporary ponds, but occurrence is greatest in lowland streams and ponds, followed by roadside ditches. Arkansas specimens have been collected during all months of the year.

The polytypic species Tropisternus collaris Fabricius is Arkansas’ second most abundant form. Of the five subspecies, two in this state, Tropisternus collaris striolatus (LeConte) is found from New York west to Kansas City, then south to eastern Texas and Florida (Spangler, 1960). This subspecies is the more common of the two in Arkansas, as 461 specimens from approximately 87 collections in 52 counties have been examined (Fig 2). It is reported from all ecoregions and occurs in diverse habitats, but is most often collected in lowland streams or bayous. Arkansas specimens have been collected from January-November.

Tropisternus collaris mexicanus LaPorte occurs from Panama north to New Mexico, then east to eastern Missouri, Arkansas and eastern Texas (Spangler, 1960). This subspecies is uncommon in Arkansas, being known from 93 specimens in 30 plus collections from 10 counties (Fig. 3). It is known from all ecoregions except Crowley’s Ridge. Discounting one collection of 32 specimens (44% of total specimens with habitat data) from Holla Bend National Wildlife Refuge, Ozark creeks and ponds (13 collections, 29 specimens) appear to be preferred habitat. Arkansas specimens were collected from January-November.

Tropisternus blatchleyi d’Orchymont is a fairly common beetle in Arkansas, where it is represented by both subspecies. Tropisternus blatchleyi blatchleyi d’Orchymont ranges from New Jersey west to northern Illinois, then south to eastern Texas and southern Florida (Spangler, 1960). We have examined 177 specimens in 69 collections from 39 Arkansas counties (Fig. 4). It occurs in all ecoregions. While it frequents diverse habitats, it is most often found in sloughs, lakes, swamps and ponds, in that order. This form has been collected from January-November in Arkansas.

Tropisternus blatchleyi modestus d’Orchymont is found from Massachusetts to northern Iowa and south to northern Arkansas and northern Virginia (Spangler, 1960). Our records extend its range much further south in Arkansas, and it should be found in Mississippi, Louisiana and Texas (Fig. 4). This form may be extending its range to the south. It is much less common in Arkansas than T. b. blatchleyi. We have seen only 34 specimens in 18 collections from 16 counties (Fig. 4). These represent all ecoregions except Crowley’s Ridge. Our habitat data suggest it may require waters of somewhat better quality than the nominate form. In Arkansas this form has been collected during February-June and September-October.

Tropisternus natactor d’Orchymont occurs from southern New Hampshire west to northern Minnesota, then south through eastern Colorado to northeastern Texas and to southern Georgia (Spangler, 1960). Accordingly, it is represented in Arkansas by 277 specimens in 98 collections from 36 counties (Fig. 5). It is found in all ecoregions, but it is clearly found most often in upland streams (58% of collections, 69% of specimens). It thus seemingly justifies its specific name. In Arkansas it has been collected during all months of the year.

Tropisternus glaber (Herbst) ranges from Maine west to extreme eastern N. Dakota, then south to northcentral Nebraska, northern Illinois and northern Maryland (Spangler, 1960). Our records, then, are new for Arkansas and extend the known range considerably to the south. This species is quite uncommon in Arkansas; 23 specimens in ten collections from four counties are known (Fig. 6). All collections were from Ozark streams; however, collections totalling six specimens were from Curia Creek at a sewage outfall (Jostus, 1980). Arkansas specimens have been collected during March, June-September and November. In our museum collection, we also have two specimens of this species which were taken in Missouri, one each from Loose Creek, Osage County, and Monroe Creek, Cooper County. These, too, are probably first records.
**Tropisternus ellipticus** (LeConie) is found from Oregon to central Iowa and east central Missouri, then south through Central America (Spangler, 1960). We report it for the first time from Arkansas. For our recent *Tropisternus* species, we have seven collections of one specimen each, and each is from a different county (Fig. 6). All specimens are from Ozark streams and were taken during January, February, April, June, July and November. Huggins and Harp’s (1983) identification of this species in Franklin County material was incorrect.

**ACKNOWLEDGMENTS**

We thank Julia R. Bollinger (ASU Entomological Collection), Chris Carlton (UA-Fayetteville Entomological Museum) and Robert Watson (UA-Little Rock Entomological Museum) for loaning specimens. Paul Spangler (Smithsonian Institution) verified identification of the *T. ellipticus* specimens.

**LITERATURE CITED**


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**THE EFFECT OF BACTERIAL LIPOPOLYSACCHARIDE-INDUCED FEVER ON THE HUMORAL RESPONSE OF NEW ZEALAND WHITE RABBITS**

The response to microbial infection and microbial products is often an elevation of body temperature commonly termed fever. It seems likely that fever may be a beneficial host response providing a mechanism that aids survival from infections (Kluger et al., 1975; Kluger and Vaughn, 1978). Kluger and Vaughn (1978) and Dinarello and Wolff (1978) noted that infected rabbits had a higher survival rate at moderate febrile levels; although, the reverse occurred at high body temperatures. Largely resulting from advertising, the American public is conditioned to routinely administer antipyretics during infections to suppress the fever response. Recently, Doran et al. (1989) reported that the healing time was prolonged in 37 children with chicken pox who received the antipyretic acetaminophen compared to 31 children receiving a placebo. Graham et al. (1990) also reported a negative effect against a Rhino virus infection when human volunteers receiving aspirin or acetaminophen produced lower titer antigens and shed virus for a longer time than those given a placebo.

The fever response can be initiated by exposing an animal to a variety of different chemical substances termed pyrogens including a number derived from infectious agents. Among the latter is bacterial lipopolysaccharide (LPS), a component of the outer membrane of Gram negative bacteria. This material produces dose-related fevers in humans and rabbits and has frequently been employed as a fever inducer for experimental purposes (Wolff, et al., 1965; Wolff, 1973). A complicating factor in predicting and assessing the potential benefits of an LPS-induced fever is the fact that injection with this material may also trigger the release of ACTH and corticosterone which can result in immunosuppression (Moberg, 1971; Yasuda and Greer, 1978; Nakano et al., 1987; Derjik et al., 1991).

The current study was undertaken to examine the effects that fever and antipyretic fever suppression might have on the humoral response in rabbits. *Salmonella typhi* lipopolysaccharide (Salmonella typhi No. L-5386, Sigma Chemical Co., St. Louis, MO) and acetaminophen were employed as the pyrogen and antipyretic respectively. Since LPS is itself antigenic, the antibody response to this substance was studied. However, to better assess the overall effects of fever and fever suppression, sheep erythrocytes were also employed as a second antigen.

Three groups each of seven New Zealand White rabbits (4.0 to 4.5 Kg) were employed in the study. Each animal was injected via a marginal ear vein on five separate days at 48 hr intervals (days 1-9) with 1.0 mL of a 10% suspension of sheep erythrocytes (S-RBC) in sterile saline. One group (S-RBC Only) received only the S-RBC while a second group (Fever Group) received an injection of a specified dose of LPS (8 ng/Kg on days one and three, 12 ng/Kg on day five, 15 ng/Kg on day seven, and 18 ng/Kg on day nine) along with the S-RBC. The increased dosage schedule was necessary because a resistance to the effects of LPS had been previously observed by day five in preliminary trials. A third group (Fever-Suppressed Group) was treated identically to the Fever Group except that acetaminophen was administered per OS in a dose of 100 mg/kg 15 minutes prior to each S-RBC/LPS injection. Immediately prior to each injection, a rabbit’s base-line rectal temperature was measured and recorded. Temperatures were then recorded at one hour intervals post-injection for a period of four hours.

Sera were collected for analysis by intracardial bleedings using clot activating Vacutainer tubes (15 mL) equipped with a 20G 1.5" needle sterile. Pre-injection samples were taken one week prior to immunization while the post-injection samples were drawn six days after the last injection. All sera were clarified by centrifugation and kept frozen for later analysis.

Antibodies against the LPS were measured by performing tube agglutination reactions using a somatic (O) antigen prepared in our laboratory from *Salmonella typhi*. Antibodies to the sheep erythrocytes were measured by direct tube hemagglutination. Both the bacterial agglutination and hemagglutination reactions as well as the O antigen preparation were done according to the procedures of Garvey et al., (1977).
The LPS injections produced an average peak rise in temperature of 1.2 C in the Fever Group while both the Fever-Suppressed and S-RBC Only Groups experienced an average peak rise in temperature of only 0.1 C. The fever was always apparent at the first measurement and in many cases was sustained throughout the four-hour period. In other instances the temperature had returned to normal after approximately 3 hours.

Bacterial agglutination reactions revealed a higher titer for post-infection antisera from rabbits in the Fever Group when compared to the Fever-Suppressed Group (Table 1). The results of the sheep cell hemagglutinations (Table 2) were similar to those of the bacterial agglutinations with the Fever Group once again providing the highest titer post-infection antisera. It was noted that the rabbits receiving only the sheep erythrocytes had an even lower titer than those in the Fever-Suppressed Group. Since both the latter groups of rabbits had the same peak rise in temperature it might be expected that their titers would also be nearly identical. The difference between the two groups was not great and might be nothing more than variation within a rather small sample of animals. The data from both serological studies suggest that the elevated body temperature of the rabbits did not act as a stressor to reduce the immune response but instead appeared to enhance antibody production. However, it is possible that the injected LPS itself simply had an adjuvant effect unrelated to the development of fever and the lower titers seen in the animals receiving acetaminophen might have been the result of some action by the drug other than anti-pyretic. Whatever the relationship might be between fever and the humoral response, it seems apparent that the administering of acetaminophen might interfere with an optimal antibody response.

### Table 1. Effect of LPS-Induced Fever and Acetaminophen Fever Suppression.

<table>
<thead>
<tr>
<th>Fever-suppressed Group</th>
<th>Fever Group</th>
<th>S-RBC Only</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre/post-injection</td>
<td>Pre/post-injection</td>
<td>Pre/post-injection</td>
</tr>
<tr>
<td>&lt;20/80</td>
<td>&lt;20/160</td>
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<td>&lt;20/40</td>
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<tr>
<td>&lt;20/160</td>
<td>&lt;20/160</td>
<td>&lt;20/160</td>
</tr>
<tr>
<td>Mean: &lt;20/114</td>
<td>&lt;20/163</td>
<td>&lt;20/163</td>
</tr>
</tbody>
</table>

Titer values are reciprocals of dilution factors. Values of <20 represent the lowest dilution tested. S-RBC Only represents injections with sheep erythrocytes but no LPS.

### Table 2. Effect of LPS-Induced Fever and Acetaminophen Fever Suppression on Hemagglutination Reactions with Rabbit Sera.

<table>
<thead>
<tr>
<th>Pre/post-injection</th>
<th>Pre/post-injection</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;20/40</td>
<td>&lt;20/160</td>
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<tr>
<td>&lt;20/80</td>
<td>&lt;20/160</td>
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<tr>
<td>&lt;20/160</td>
<td>&lt;20/160</td>
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<tr>
<td>Mean: &lt;20/93</td>
<td>&lt;20/143</td>
</tr>
</tbody>
</table>

Titer values are reciprocals of dilution factors. Values of <20 represent the lowest dilution tested.

### ACKNOWLEDGMENT

This project was supported by an Institutional Research grant provided by Arkansas State University. Recognition also is extended to M. Abdul Khalil for preliminary studies with LPS and antibody production.

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LAWRENCE W. HINCK and STANLEY N. DAVID Department of Biological Sciences Arkansas State University State University AR 72467.
TECHNIQUES FOR EFFICIENCY CALIBRATION OF PHOTON DETECTORS FOR X-RAYS AND LOW ENERGY GAMMA RAYS

In atomic-nuclear physics, information about internal structure is contained in the x-rays and γ-rays emitted. Semiconductor photon detectors like Si(Li), HpGe efficiently detect and quantize the yield of emitted photons. In order to normalize these yields and convert them to cross section for production of the photons, it is essential to know the efficiency of the detector used. Measured cross section can then be compared with cross section values predicted by the theoretical models (Duggan, et al., 1985). This comparison is more meaningful if the uncertainties in the data are small. In measuring x-ray and γ-ray production cross section experiments strive to reduce errors to a few percent. A large part of the error comes from uncertainties in the efficiency. To make accurate measurement of x-ray and x-ray production cross sections it is imperative that efficiency be known to a high degree of accuracy. Using several techniques to measure or calculate the efficiency in a region of photon energy and then averaging these results minimize the overall uncertainties in the determined efficiency value.

In the present work, techniques for measuring efficiency of detector will be reviewed from the standpoint of the type of the detector, the energy range of the photons to be studied with the detector and the uncertainties that arise. Origin of the uncertainties and their effect on the overall uncertainty in the efficiency values will be explored.

The primary method of measuring efficiency utilizes calibrated radioactive sources (Gallagher and Cipolla, 1974). The calibration gives their activities and standard tables provide rates of emission of the x-rays and γ-rays from the source. The energies of these photons should also be known to a high degree of accuracy. Ideally a point source is preferred for the geometry to be used with the source and the detector. From the activity of the source and a knowledge of half-life of the radioactive decay involved, the disintegration rate of the source isotopic nuclei on any date can be calculated. Uncertainty comes in the calculation via both the half-life and the activity quoted. The efficiency of the detector, ε, at the energy of the photon, E, is then given by

\[\epsilon = \frac{\langle d\Omega/4\pi \rangle \langle \text{# photons measured/time}\rangle}{\text{Activity. (x or } \gamma \text{ emission rate/disintegration)}}\]  

where \(d\Omega\) is the geometrical factor related to the solid angle subtended by the point source at the detector position. The limitation of this technique is the non-availability of a calibrated source for \(< 3 \text{ keV}\) energy region that is being studied. Among the available sources, the 3.3 keV M-shell x-ray line in an open/(unshielded) \(^{26}\)Am source is the lowest energy line available for efficiency determination studies (Campbell and McNelles, 1974). This line has a comparatively large (9\%) uncertainty quoted for its emission rate. Most of the higher energy lines in this source (e.g. 13.9 keV, 26.5 keV, 59.6 keV) are well suited for accurate efficiency determination as their emission rates are known to uncertainties of 1-2\%. For energy regions above \(~5 \text{ keV}\), assuming activity uncertainties are below 5\% and other parameters in eq. (1) can be measured to accuracies of 1-2\%, the overall uncertainty is \(< 5\%\). But for regions at \(3 \text{ keV}\) errors propagate to at least 14\%. Figure 1 was determined with a calibrated source of \(^{26}\)Am. The efficiency at \(\epsilon\) is above \(5 \times 10^7\) between 10 and 30 keV and falls off at other energies.

Figure 1. The efficiency of Si (Li) detector as a function of photon energy in keV. The beryllium window has a thickness of 0.62 μm. The resolution of the detector at 5.9 keV is 165 eV.

The method of determining the yield of the x-ray or the γ-ray yield from the measured spectrum is another crucial aspect in reducing uncertainties. The basic procedure here is to subtract a properly drawn background and fit the resulting spectrum with peaks of appropriate line shapes. The fitting algorithm has to take into account whether the peak represents a x-ray or a γ-ray (Gunnink, 1977). The line-shapes of the peaks representing x-ray or γ-rays are dependent on their origin, atomic for x-rays and nuclear for γ-rays. The x-ray shapes are non-gaussian because of their long tails and hence described better by Voight function while x-rays have a natural line shape given by Lorentzian function (Debertin and Pessara, 1981). The resolution of the detector also affects the fitting procedure as peaks become resolved or not depending on the resolution. Then there is the question of the detector response to the photons (Yacout, et al, 1986). Basically the interaction of the photon in the active region of the detector is via photoelectric effect. Compton effect adds to the overall shape of the spectrum and for low energies (<150 keV) the other mechanisms that contribute are the Auger electrons and the escape peaks generated by the element of the detector (Silicon for Si(Li) and Germanium for HpGe). Monte Carlo calculations (He et al., 1988) of the detector response function allows one to have a better understanding of these mechanisms.

Figure 2. Efficiency of the Si(Li) detector vs. the x-ray energy.
The second technique (Gallagher and Cippolla, 1974) is based on the calculation of attenuation of photon intensities in traversing the various layers before the photon reaches the active region (active silicon in a Si(Li) and the active Germanium in a HpGe detector) of the detector. A typical set of layers is comprised of, starting from outside, a thin mylar film (C_{10}H_{14}O_2), beryllium window, gold contact layer and dead layer (No electrical pulses are generated from this region of the crystal and hence the terminology dead). The attenuation depends on the thickness (x) of the layer and its mass absorption coefficient (\mu) at the photon energy. The intensity attenuation is given by the exponential law

$$I = I_0 e^{-\mu x}$$

The intrinsic efficiency, \(e\), as a function of the energy of photon, \(E\), in terms of a \(\alpha_0\), the geometrical factor, is given by

$$e = \alpha_0 \cdot e^{\alpha E} \cdot [1 - e(x / \alpha E)]$$

where \(\alpha, \beta, \gamma, \delta\) are the parameters. The efficiency curve determined from eq. (3) is normalized via efficiency numbers generated from the method of calibrated sources at a common point in energy. This normalized curve then allows one to read efficiency values at energies of photons below 3 keV. The uncertainties also arise from absorption edges of Si-K shell and Au-M shell. The photon absorption at these edges result in abrupt changes in the efficiency curve at the energies of these edges. The typical efficiency curve, at 1 keV and below, shows a sharply dropping efficiency with decreasing energy. Starting with 14\% at 3.3 keV the uncertainties only keep increasing with decreasing energy. It becomes essential in the region below 3.3 keV, especially below 1 keV, to use another method for determination of efficiency that would allow one to average efficiency and reduce uncertainties.

The technique proposed by Lenard and Phillips (1979) allows one to determine efficiency accurately in 0.5 - 8.4 keV range. In this method K-shell x-rays from targets of low Z elements (Z < 8-29) is measured for incident proton and helium ions. The x-ray yield is normalized to the theoretical cross section for K-shell x-ray production and efficiency determined. The efficiency for K-shell x-rays of each element is given by

$$\varepsilon = \varepsilon_{Kx} \cdot D_{\varepsilon x} \cdot e_{\varepsilon Kx}$$

where \(\varepsilon_{Kx}\) is the net yield of K-shell x-ray, \(D_{\varepsilon x}\) is the dead time correction for x-ray detector, \(e_{\varepsilon Kx}\) is the differential Rutherford cross section, \(\Omega\) is the solid angle subtended by the particle detector, \(\varepsilon_{Kx}\) is the net yield of the scattered particles, \(D_{\varepsilon x}\) is the dead time correction for the particle detector, \(\eta\) is the efficiency of the x-ray detector at Kx x-ray energy, S is the correction for self-attenuation of the x-rays in the target foil. Figure 2 shows efficiency of Si(Li) detector for x-ray energies below 3 keV determined following this procedure (Duggan et al., 1985). The solid curve was determined by attenuation method as described by eq (2) and eq (3). Good agreement is seen between the efficiency determined by the two methods. Even with this good agreement and overall reduction in the uncertainty in efficiency, there is still >10\% uncertainty. Equation (4), when rearranged and solved for \(\varepsilon_{Kx}\) allows one to calculate photon production cross section. The uncertainty in the efficiency is then propagated to \(\varepsilon_{Kx}\) according to eq. (4). It turns out that uncertainties in all other parameters in eq. (4) can be reduced to <5\% most of the times. Hence the largest uncertainty in cross sections comes due to uncertainty in the efficiency. Therefore it is essential that uncertainty be known to a great degree of accuracy.

In order to determine efficiency of a windowless Si(Li) detector to a high degree of accuracy, down to 600 eV, researchers have successfully used the measurement of atomic field bremsstrahlung (Weathers et al., 1991). Bremsstrahlung spectrum is a slowly varying function of energy. This radiation was measured from targets of Al, Ag and Au for incident beam of 66.5 keV electrons. The measured Bremsstrahlung Spectra was compared to the theoretically predicted Bremsstrahlung distribution and an intrinsic efficiency was generated. The efficiency determined with a calibrated radioactive source at 5.4 keV allowed for absolute normalization of the efficiency curve. To summarize, the efficiency of a detector, an important parameter in determination of photon production cross section, can be determined by different techniques. The choice of technique depends on photon energy. Some of these techniques allow one to extend the range of energies covered while the overlapping energy regions covered in these techniques provide for reduction of uncertainty in the efficiency.

In conclusion, efficiency plays an important role in determination of photon production cross section and the uncertainty there in. The overall uncertainty in the efficiency can be reduced by combining efficiency determined via various techniques.

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 sequentioal occupation of cavities by red-cockaded woodpeckers
and red-bellied woodpeckers in the ouachita national forest

for competition to exist, there should be scarcity of a resource required by more than one species. the use of this resource by one species should adversely affect the other species (pianka, 1983). red-cockaded woodpeckers (picoides borealis) are virtually unique in excavating cavities in mature living pines used for nesting and roosting (jackson, 1971). this habitat of old pines maintained as open stands by periodic fire is essential for p. borealis in the southeast (uspws, 1985; jackson, 1988). this habitat and the cavities of p. borealis also are attractive to other cavity nesting species (jackson, 1978a; everhart, 1986), including red-bellied woodpeckers (melanerpes carolinus), which occur sympatrically with p. borealis in arkansas (jackson and neal, 1986). at a time when most of the original widespread habitat of old-growth pine in open, fire-maintained stands has disappeared (lennartz et al., 1983), the potential for cavity competition between cavity using species has increased. the purpose of this study was to evaluate the impact of this potential competition and to test a method of protecting cavities of p. borealis.

we monitored 15 clusters of cavity trees of endangered p. borealis in the ouachita national forest in scott and polk counties of west-central arkansas from february 1990 to march 1992 (neal and montague, 1991). these cavity trees are shortleaf pines (pinus echinata) that occur in maturing stands of second-growth pine or mixed pine-hardwood.

our monitoring included: 1) observing birds as they entered or departed from roost cavities in mornings and evenings, 2) climbing cavity trees and inspecting cavity interiors with a light and mirror, and 3) recording use of these cavities by species other than p. borealis. active use by p. borealis was determined by noting cavity tree characteristics, including rottenness of bark around the plate at the cavity entrance and whether or not resin wells were being actively worked by p. borealis (jackson, 1977; 1978b). our monitoring was most intensive during the breeding season of p. borealis (late april-early july), but included all seasons of the year. all p. borealis in the forest were marked with unique combinations of color bands so that individual birds could be recognized in the field.

when we discovered that an active p. borealis cavity had been usurped by another species, we took steps to exclude that species. in most cases we installed a cavity entrance restrictor (carter et al., 1989), which usually leads to exclusion of species, like m. carolina, that are larger than p. borealis. in one case, we physically removed the usurper from the area. we also removed any foreign materials inside the cavity, such as nesting material. these activities were followed up with additional monitoring of the cavities in order to assess the affects of our activities. our work was designed to reactively reduce or restrictor installation, or p. borealis to exclusion of the cavity usurper.

our monitoring and subsequent field work revealed that red-bellied woodpeckers occupied 8 of approximately 40 active or recently active cavities of red-cockaded woodpeckers (table 1). in 6 cases, our installation of a cavity restrictor or physical removal of m. carolina from the area (1 case) was effective in restoring the cavity for use by red-cockaded woodpeckers. p. borealis readily accepts cavity restrictors (carter et al., 1989; raulston, 1992). one of these recaptured cavities which was fitted with a restrictor was subsequently used for nesting by p. borealis.

in compartment 323, stand 13 (table 1), m. carolina occupied an inactive p. borealis cavity in tree 2-4. when this cavity was restricted, m. carolina was excluded and the male p. borealis abandoned his former cavity in tree 2-2, which had been restricted at the same time. subsequently, another p. borealis began roosting in 2-2, which eventually became the nest cavity for a second year (1991 and 1992).

in one instance, we were not able to restore the cavity usurped by m. carolina to its former occupant. on 25 april 1991 we found a dead juvenile male p. borealis lodged in the entrance tunnel of its roost cavity. we had previously trapped and banded this bird at this same cavity. following removal of the dead p. borealis, a dead m. carolina was discovered in the cavity. finally, in one case our exclusion of m. carolina from a recently active p. borealis cavity did not result in reoccupation by p. borealis. this cavity was instead usurped by a southern flying squirrel, glaucomys volans, a frequent occupier of p. borealis cavities in the ouachita national forest and elsewhere in the southeast (table 2).

we report the use of red-cockaded woodpecker cavities by other species, including red-bellied woodpeckers, is rangewide to the southeast (table 2). jackson (1978a) found that m. carolina was the most important user of p. borealis cavities in his study areas in mississippi, georgia and south carolina. in north carolina, everhart (1986) reported that during the period 1978-1981, 34% of the avian occupants of p. borealis cavities were m. carolina. however, use of p. borealis cavities by other species, including m. carolina, is not in itself evidence of competition for these cavities. many factors contribute to cavity abandonment by p. borealis (rudolph et al., 1990). in oklahoma, wood (1983) found no instance of p. borealis engaged in interspecific defense of cavities. in
Arkansas limitation.

On the other hand, our evidence of aggressive encounters between these two woodpeckers in the Ouachita National Forest, including an encounter that resulted in death, is not unique. In Florida, Ligon (1970, 1971) found that defense of nest cavities from M. carolinus was an important part of daily activities of P. borealis. Baker (1983) thought such interactions may have played a role in the decline of a P. borealis population. There have also been several previous observations of P. borealis killed by M. carolinus (Jackson, 1978a; Ligon, 1971) and M. carolinus killing young or taking eggs of other bird species (Stickle, 1963; Brackbill, 1969; Rodgers, 1990).

We are not arguing that Red-cockaded Woodpeckers became endangered because of interspecific competition. Rather, rarity resulted from massive rangewide habitat degradation as a result of fire suppression that reduced the quality of once open pine forests and removal of mature forest that reduced the supply of mature, live pines required by this woodpecker for cavity excavation (USFWS, 1985; Ligon et al., 1986).

Recent experiments have shown that a key limiting factor in P. borealis population expansion is availability of suitable cavities (Walters, 1991). When suitable artificial cavities were supplied, P. borealis was induced to form new breeding units. Our work in the Ouachitas showed that the loss of cavities resulted from interspecific conflicts rather than voluntary abandonment by P. borealis. We hypothesize that the natural sequence of cavity use is upset in a situation where suitable trees and high quality cavities are in short supply, with the result that sympatric species are forced into conflict. In a period in which suitable habitat is in critically short supply, management techniques which reduce the effects of competition for high quality cavities can potentially speed the recovery of P. borealis. Management tools including use of cavity restrictors, physical removal of usurping M. carolinus, and installation of artificial cavities serve to increase the number of suitable cavities that can be used by P. borealis.

These are proximate solutions to the problem of cavity limitation. Ultimate solutions lie in the maturation of existing pine stands and managing periodic use of prescribed fire to maintain these stands in an open condition.

LITERATURE CITED


A MATERNITY COLONY OF GRAY BATS IN A NON-CAVE SITE

Colonies of the endangered gray bat, Myotis grisescens, are primarily found inhabiting caves in the limestone karst regions of Arkansas, Missouri, Kentucky, Tennessee, and Alabama (Barbour and Davis, 1969). There are only two previously published accounts of gray bats inhabiting non-cave sites. In 1964, Hayes and Bingman reported the presence of a maternity colony in a storm sewer in Pittsburg, Kansas, and Gunier and Elder (1971) studied a maternity colony roosting in an old barn in Missouri. In 1988, another maternity colony was found inhabiting a storm drain in Newark, Independence County, Arkansas. The town has a population of approximately 1100 and lies at the extreme eastern edge of the Ozark Plateau.

Because of the endangered status of the gray bat, precautions were taken during our activities to provide minimal disturbance to the colony. The physical and structural characteristics of the drain were studied in winter or after emergence when the maternity colony was not present. Temperatures at the roost site were monitored by means of a temperature transducer connected to a microprocessor-based data acquisition system mounted at the tunnel entrance. The population was estimated by direct count upon emergence.

The western inlet of the storm drain, at the intersection of Front and Main Streets, measures 7 m across by 1.7 m in height. The tunnel itself is 160 m long and runs southwest under the sidewalk, Highway 122, and Paraquete Road after which it empties into a creek bed by means of two rectangular concrete culverts approximately 1 m high by 2 m wide.

Since there are two openings to the drain as well as several sidewalk grates and drain openings to the street, air circulates through the drain and ammonia levels do not build up. Gasoline fumes from a service station, however, are sometimes present.

The walls and ceiling are constructed of reinforced concrete with the exception of an older section along Front Street where sandstone blocks make up the lower walls. The horizontal ceiling is not a uniform height above the floor, but is constructed in sections, some of which are lower than others. The floor of the sewer consists of coarse gravel and small cobbles. In some parts of the drain the floor is nearly level, but in others there are depressions and gravel bars so that the height of the floor may vary by as much as 5 m across the width of the drain. The topography of the floor changes from year to year depending on the water flow. At the time of the survey, the maximum height measured from gravel to ceiling was 1.9 m, 1.45 m above the water level. The minimum height above the floor was 1.1 m, .89 m above the water. The width of the drain also varies from a maximum of 4.6 m to a minimum of 3.3 m. The sewer is smallest in height and width in the section under Highway 122.

Water is present in the drain all year, but depth varies depending on floor topography and precipitation. During heavy rains water depths of over 1.5 m completely flood the tunnel west of Hwy. 122 as well as the outlet culverts.

Unlike natural caves, the temperature near the ceiling of the drain can fluctuate up to 10 degrees Celsius per day. In sunny weather there is a regular cycle of heating and cooling in the drain dependent on changes in air temperature and heating of the pavement and concrete. Heat from above is transferred to the roof environment through the concrete even on days when the air is cool.

There are two roost sites in the storm drain as determined by ceiling stains. It is not known if the maternity colony uses both sites, but they do serve as night roosts and hibernation sites for a small group of gray bats. Maternity colonies require warm temperatures to promote rapid growth of the young. In natural caves, rooms with domed ceilings to trap the colonies' heat are chosen for bearing and raising young. Such roosts are generally located over water to provide humidity and protection from disturbance and predation (Tuttle, 1975). The primary roost site of the maternity colony in Newark exhibits these same characteristics. It is located 50-65 m from the outlet of the drain in the section between Paraquete Road and Highway 122, where the sewer attains its maximum height and width. There the ceiling rises forming a rectangular dome. This heat trapping dome, along with the increased dimensions of the site, prevent flood waters from reaching the ceiling. Permanent pools of water up to 0.7 m deep are present beneath the roost site. In the summer when the maternity colony is present the temperatures at the primary roost site average 34 degrees Celsius and may rise to 40 degrees.
The smaller secondary roost site is located 50.53 m from the entrance on the west side of Hwy 122. The floor is nearly level and generally has 1-2 cm of water flowing over it. The lack of the ceiling dome and the narrowed dimensions of the drain downstream make this site prone to flooding. The flat ceiling is slightly eroded with exposed reinforcing rods and a deep crack between ceiling sections that is used as a hibernation site by 20-30 gray bats. Ceiling holes at the primary site are also used in this manner. Natural caves chosen by hibernacula have high humidity and an average temperature of 7-10 degrees Celsius (Barbour and Davis, 1969). The bats may choose a site 10-15 degrees warmer in the fall and then remain there as the temperature drops to the 0-5 degree Celsius range. In the same manner, temperatures in the storm drain drop gradually as days get colder. In the coldest months, temperatures may fall to 8.5 degrees or below. They do not remain stable, however, as they would in a cave. On warm days temperatures rise. Under these conditions, the bats do not remain torpid but become active, move about, and may emerge to feed.

Maternity colonies prefer caves near a river or reservoir over which the adults feed. Few are located more than 4 km from a major body of water. Forested lands are also used as forage areas by newly volant young and by adults on their way to the water (Tuttle, 1976). The maternity colony at Newark is also located near several bodies of water: the White River 4.5 km to the south, the Black River 7 km to the east, and Dora Creek 3 km to the northeast. Upon emergence, most members of this colony appear to head northeast toward Dora Creek, the closest water source, foraging in the trees as they go. Others, however, feed in the area and use the storm drain as a night roost.

Disturbance to colonies is one of the major causes of the decline in gray bat populations (Tuttle, 1979). The storm sewer population, estimated in both 1989 and 1990 to be close to 8000 people, appears to be stable, however, disturbance to the Newark colony is a real threat because it is located in a town. Children have been known to kill the bats as they emerge from the west entrance. The fear of snakes thought to live in the drain and fear of the bats themselves have kept people away from the maternity roost site, although children do play in the west drain entrance. Noise from people, street traffic, and trains does not seem to affect the colony, as it has been returning to this roost for many years.

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NEW RECORDS OF VERTEBRATES IN SOUTHWESTERN ARKANSAS

The vertebrate fauna of southwestern Arkansas is less well known than that of other regions of the state; this possibly reflects the distance of the region from major universities. The geographic area is located almost entirely within the West Gulf Coastal Plain natural division (Foti, 1974). Recent work relative to the vertebrate fauna of the southwestern quadrant of Arkansas has alleviated some of the regional bias in information on vertebrates (Baker, 1985; James and Neal, 1986; Robison and Buchanan, 1988; Robison et al., 1983; Stalander and Heidt, 1990; Sewell, 1981; Steward et al., 1986, 1989a,b). This report documents new records of distribution and provides notes on natural history of selected vertebrates from southwestern Arkansas.

Field collections and observations were made by the authors and students at Henderson State University. Fishes were obtained by use of seine, amphibians and reptiles by overturning cover materials or driving down roads on rainy evenings (with the exception of a turtle caught on a trotline), and mammals were collected as road-killed specimens or by use of museum special or Sherman traps. Birds were recorded photographically.

Specimens of fishes were fixed in 10% formalin and stored in 40% isopropanol. Amphibians and reptiles were preserved in the same manner as fishes, or preserved by use of a freeze-drier. Specimens of mammals were prepared as standard skins and skeletons. All specimens were deposited in the collection of vertebrates at Henderson State University.

Class: Osteichthyes


Semotilus atromaculatus (Mitchell), the Creek Chub, Family Cyprinidae. One record taken from the Saline River was collected prior to 1960 (Robison and Buchanan, 1988). The present occurrence of the creek chub in the Saline River is confirmed by a single specimen from Howard County south of Dierks Lake near Bluff Creek, in March 1991.

The extreme headwaters of the Cossatot River provided the only other specimens of the creek chub from the Red River drainage (Cloutman and Olmsted, 1974). New records include a specimen taken in April 1991 from Bois d’Arc Creek (a tributary to the Red River) in Hempstead County, about 3 km southwest of the junction of Arkansas Highways 73 and 195. An additional specimen was collected in February 1991 in Little River County from the Little River just south of the dam forming Millwood Lake.

Centrarchus macropomus (Lacepede), the Flier Sunfish, Family Centrarchidae. Robison and Buchanan (1988) indicated records of the flier sunfish in the Red River drainage from Bodcaw Creek (Hempstead County) and Dorchat Bayou (Cochran County). These streams enter the Red River in Louisiana. A specimen collected in March 1991 from Hempstead County represents the westernmost record for Arkansas and is marginal to the general species range. The location of collection (a tributary to Yellow Creek on Highway 32, about 4.5 km northeast of the Millwood Lake Dam) documents the flier sunfish in the Little River drainage.
Percina caproder (Rafinesque), the logperch, Family Percidae. The logperch has been reported from the Little River and its tributaries, but previously only above Millwood Lake (Robison and Buchanan, 1988). A specimen collected in February 1991 from Little River below the dam for Millwood Lake (Little River County) is the most southern record in the Red River drainage of Arkansas.

Percina maculata (Girard), the Blackside Darter, Family Percidae. The only record of the blackside darter in the Red River drainage of Arkansas was collected prior to 1960 in Lafayette County from Bocodaw Creek (Robison and Buchanan, 1988). A specimen collected in March 1991 from Bois d'Arc Creek (a tributary to the Red River) in Hempstead County about 3 km southwest of the junction of Arkansas Highways 73 and 195 extends the range northwestward and closer to the channel of the Red River in Arkansas, and provides recent documentation of the presence of this darter in the Red River drainage.

Class: Amphibia

Knowledge of the distributions of amphibians and reptiles in Arkansas has not been coalesced since the review by Dowling (1957). Conant and Collins (1991) provided maps that include Arkansas distributions of amphibians and reptiles.

Eurycea holbrooki (Holbrook), Dwarf Salamander, Family Plethodontidae. Dowling (1957) reported specimens from Fayetteville and Miller counties in southwestern Arkansas. A species was collected in April 1991 near the regaugulating dam on the Red River, in Clark County. The specimen was collected within a clump of mosses. This location represents the most northwestern record for the species (Conant and Collins, 1991), although unverified museum records may extend the range even farther north (S. E. Trauth, pers. comm.).

Scaphiopus holbrooki hurteri Strecker, Hunter’s Spadefoot, Family Pelobatidae. Museum records compiled by M. V. Plummer and S. E. Trauth indicate that specimens have not been previously collected from Clark County. A specimen was collected near the campus of Ouachita Baptist University in Arkadelphia in February 1991.

Class: Reptilia

Micrurus fulvius tenere (Baird and Girard), Texas Coral Snake, Family Elapidae. The coral snake is secretive and is seldom collected. Dowling (1957) reported specimens from Nevada, Miller, Hempstead, and Ouachita Counties, and Robinson (1972) added records for Lafayette and Union Counties. Because of the rarity of collection, we document another individual from Nevada County collected in October 1988. The specimen was found in a sandy area of a predominantly pine forest, located about 3 km west of Cali.

Cemophora coccinea copei (Jan), Scarlet Snake, Family Colubridae. The scarlet snake is very secretive and is typically associated with soils in which it can burrow. Thus, few records of its occurrence are available: Dowling (1957) reported the species from Pike County in southwestern Arkansas. Although the species probably occurs almost statewide, records are still uncommon (Reagan, 1974). A specimen was collected in June 1991 at Camp Clearfork in Garland County, about 5 km west of Crystal Springs off highway 270. A Clark County specimen was collected in Arkadelphia at the Physical Plant of Henderson State University in May 1992.

Virginia valeriae elegans Kennicott, Western Earth Snake, Family Colubridae. Dowling (1957) noted that specimens were known only from the highlands north of the Arkansas River, but that the species may be found over the state. A specimen was collected in August 1991 about 3 km west of Arkadelphia, Clark County, on a road connecting Arkansas Highways 8 and 51.

Macrolemys temminckii (Harlan), Alligator Snapping Turtle, family Chelydridae. Although this turtle has a statewide distribution, few specimens are available - possibly due to the large size the turtle may obtain and therefore the difficulty in preparation and storage. There is special concern for this species due to habitat losses and its vulnerability to shooting and capture in fishing nets and on trotlines. Dowling (1957) recorded a specimen from Hempstead County.

In April 1991, an individual was observed by RT in the Caddo River just below the regulation dam for Lake DeGray, Clark County. Carapace length was estimated (visually) to be about 35 cm. A specimen from Clark County was obtained from a trotline in August 1991, in the Little Missouri River about 1.5 km northwest of the confluence of the Little Missouri and Ouachita Rivers. Carapace length for this specimen was 25 cm. An additional specimen, identified from a photograph in the possession of RT, was snagged in May 1990 by a fisherman in the Little River below the Millwood Lake Dam, Little River County. Researchers interested in status surveys should note the possibility that these turtles may congregate below dams to search for food.

Class: Aves

Anhinga anhinga (Linnaeus), Anhinga or “water turkey”, Family Anhingidae. Anhingas are known as summer residents on a few swampy areas in the Mississippi Alluvial Plain and on the West Gulf Coastal Plain. Nesting has been reported in Jefferson County in southeastern Arkansas (Meanley, 1954) and in Hempstead, Lafayette, and Little River counties of southwestern Arkansas (James and Neal, 1986). Anningas have been observed in Saline, Lonoke, Pulaski, and Hot Spring counties, but not in association with nests (James and Neal, 1986). Because of loss of habitat, James (1974) considered the Anhinga to be endangered as a breeding bird in Arkansas.

Nesting Anhingas were observed in Clark County during three successive years (1983 - 1985). The habitat was located in the Little Missouri bottoms approximately 8 km downstream from the Highway 67 bridge. Anhingas usually arrived around the middle of April, and nests were occupied by mid-May. Nest construction was not directly observed; however the same nests were reoccupied each year. Birds were observed on the nest during the third week of May. Clutch size was undetermined, but each of three nests observed in 1983 and 1984 produced two young. In 1985, three pairs attempted nesting with success in only one nest, which produced two young.

Young were being fed in two nests on 10 June 1983, but feeding of young was not observed in the third nest until 20 June. By 12 July, all young had fledged. No further attempts at nesting have been observed since 1985, although birds routinely have been sighted each year.

The most productive nest was in a large bald cypress (Taxodium distichum) located about 15 m from the nearest shoreline. The nest was on the lowest limb of the tree, about 10 m above the water, and water depth was one m. The other two nests were located in twin forks of a damaged cypress. These nests were about 60 m from the nearest shoreline and about 12 m above water, one nest slightly higher than the other.

Anhingas swim with the body submerged and must exit the water to dry their feathers before flying, making them vulnerable to predators. At least three alligators (Alligator mississippiensis) also occupied the cypress trunks. Anhingas avoided alligators in part by hopping up inclined logs or debris to attain elevated positions. Inclined structure may be important as habitat when Anhingas and alligators are in association.

Class: Mammalia

Recent surveys have appreciably increased our knowledge of the distribution of bats, rodents, and carnivores of southwestern Arkansas (Steward et al., 1986, 1989a,b). These studies examined the occurrence of 48 species of mammals in 21 southwestern counties. Sealander and Heidt (1990) documented known distributions of other mammals.

Bairama carolinensis (Bachman), Southern Short-tailed Shrew, Family Soricidae. Sealander and Heidt (1990) indicated this shrew in most counties of southwestern Arkansas. A specimen collected in November 1991 near Malvern, Hot Spring County, represents a new county record.

Plecotus rafinesquii Lesson, Rafinesque's Big-eared Bat, family Vespertilionidae. This big-eared bat has been collected in Calhoun, Columbia, Dallas, Grant, Lafayette, Little River, Nevada, Ouachita, and Union counties of southwestern Arkansas (Steward et al., 1986). Typical roosting habitat includes barn loft, attics, and old buildings (Sealander and Heidt, 1990). A Clark county record was obtained in November 1987 about nine km southeast of Gurdon. The specimen was taken from a covered brick well in which it was roosting.
Tamias striatus (Linnaeus), Eastern Chipmunk, Family Sciuridae. The chipmunk is generally found in deciduous forests with rocky outcrops or piles of wood or rock which it uses for cover and as lookout posts. These requirements limit the distribution of the chipmunk in southwestern Arkansas, and specimens have been reported from Garland, Pike, and Polk counties - all within the Ouachita Mountain region (Sealander and Heidt, 1990; Steward et al., 1989a). A specimen was collected in October 1991 in Clark county, about 3 km west of Arkadelphia near a road connecting Arkansas Highways 8 and 51. The specimen was taken from a wooded area but without the typical rock present, and the location is slightly inside the Gulf Coastal Plain portion of Clark County. Chipmunks also have been observed in Clark County 5 km west of Hollywood (off Highway 26) in forest habitats about 3 km south of rocky areas. These individuals were observed during a control burn, having been smoked out of a hollow log.

Oryzomys palustris (Harlan), Marsh Rice Rat, Family Muridae. The marsh rice rat typically occupies wet habitats. Records indicate the presence of this rodent in 10 southwestern Arkansas counties (Steward et al., 1989a). Two new county records are reported here. In January 1992, two specimens were collected in Clark County near a beaver swamp about 5 km west of Arkadelphia off Highway 51. Three specimens also were collected in Hot Spring County in January 1992. These specimens were taken from a field adjacent to Drowning Slough located about 6 km southwest of Malvern.

Mesoictani floridana (Ord), Eastern Woodrat, Family Muridae. The woodrat occurs statewide (Sealander and Heidt, 1990) but has been reported in southwestern Arkansas from nine counties only (Steward et al., 1989a). Over a three year period, 10 specimens have been collected from a barn located about 4 km west of Arkadelphia off a road connecting Highways 8 and 51. These specimens represent a new county record for Clark County.

Reithrodontomys fulvescens (J. A. Allen), Fulvous Harvest Mouse, Family Muridae. This mouse occurs statewide (Sealander and Heidt, 1990) and has been reported in southwestern Arkansas from 14 counties (Steward et al., 1989a). A Clark County record was collected near a beaver swamp about 5 km west of Arkadelphia off highway 51, in January 1992.

Ochrotomys nutalli (Harlan), Golden Mouse, Family Muridae. The golden mouse has been reported from 11 southwestern Arkansas counties (Steward et al., 1989a). A Clark County record was taken about 5 km west of Arkadelphia off highway 51, in January 1992.

Microtus pinesteror (Le Conte), Woodland Vole, Family Muridae. This vole has been reported from 13 southwestern Arkansas counties (Steward et al., 1989a). A Clark County record was collected near a beaver swamp about 5 km west of Arkadelphia off Highway 51, in February 1992.

Ondatra zibethicus (Linnaeus), Muskrat, Family Muridae. The distribution map of Sealander and Heidt (1990) indicated no specimens from southwestern Arkansas. Steward et al. (1989a) also failed to obtain specimens to document their presence, although reports by local people suggested their occurrence. A specimen collected in January 1983 about 19 km southeast of Arkadelphia documents the muskrat in Clark County.

Mastela vison (Schreber), Mink, Family Mustelidae. The mink is a semi-aquatic species occurring statewide (Sealander and Heidt, 1990); however Steward et al. (1989b) was able to document their occurrence in only five counties of southwestern Arkansas. A road-killed specimen collected on Highway 67 near the Arkadelphia city limits provides a Clark County record.

ACKNOWLEDGMENTS

We thank the people who assisted with information or in the collection of specimens: J. D. Bragg, D. A. Cowling, S. Davis, R. Hicks, R. L. McKinley, W. R. Stiffler, S. E. Trauth, C. C. Tumilson and J. E. Wheatley.

LITERATURE CITED


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Raccoons are omnivorous and have been categorized as solely opportunistic in their feeding habits. Fruits, insects, acorns, and crayfish are normally the main dietary constituents during fall and winter (Johnson, 1970). Hamilton (1936) examined 127 raccoon stomachs taken during the fall and winter from the New York area. Plant material (acorns, fruits, etc.) comprised 73.8%; animal foods (small mammals, insects, crayfish, etc.) represented 26.1%, the remaining 1.5% was garbage. Gies (1939 and 1940) collected scats and stomachs of raccoons from central and eastern Iowa. Plant material made up 70% of the total with animals and insects representing the remaining food items found. In eastern Texas, Baker et al. (1945) studied the food habits of raccoons from September 1940 through June 1942. During this period, a total of 378 scats, stomachs, and intestinal tracts were analyzed. Over the entire year, plant foods exceeded animal foods by 40 to 60 percent. Acorns (Quercus) and crayfish (Cambamus) were the two principal foods revealed by their study, comprising more than half the total volume taken. Both items appeared in the diet during every month. During the winter, acorns averaged more than half of the total volume taken. Rivest and Bergeron (1981) in a two year study of raccoon food habits found that plants made up 96% of food items. This may be somewhat biased toward plants since the study was conducted in an area where corn was the major field crop.

The purpose of the present study is to describe the winter food habits of male and female raccoons from different age classes and from the various physiographic regions of Arkansas.

The geographical scope of this study included all habitats within the political boundaries of Arkansas. Foss (1974) divides Arkansas into four major physiographic regions: the Ozarks, Ouachitas, Mississippi Alluvial Plain (Delta), and Gulf Coastal Plain (GCP). The Ozark Mountains lie in the northwestern region of the state, with the Ouachita Mountains to the south and the Mississippi Alluvial Plain to the east. The Ouachita Mountains lie between the Ozark Mountains to the north, the Gulf Coastal Plain to the south and Mississippi Alluvial Plain to the east. The Mississippi Alluvial Plain, occupies the eastern portion of the state, and is bounded to the southwest by the Gulf Coastal Plain and to the west and northwest by the Ouachita and Ozark Mountains. The Gulf Coastal Plain lies in southern Arkansas, contacting the Ouachita Mountains along its northwestern and the Delta along its northeastern boundaries. These four physiographic regions form the geographic framework of this study.

Carcasses utilized in this study were collected from furbuyers and trappers during the regular Arkansas trapping seasons of 1981-82 and 1982-83. Trapping seasons in Arkansas generally extend from about 1 December through 31 January, with a two-week grace period in February for furbuyers to complete their business transactions. Stomach collection data for the 1981-82 and 83-84 trapping seasons. For each carcass, the skull was removed and tagged as a museum specimen, and stomachs were removed, tagged, and frozen (Korschgen, 1971) for later examination. A lower canine was extracted for cemental analysis. Analysis of dental cementum is a widely accepted method for age determination for many mammals. Grau et al. (1970) found that the canine foramen closes at approximately 12 months of age in raccoons. For this reason, teeth having an open root tip, were considered to be less than one year of age and taken no further in the aging process. All teeth having a closed root tip were processed according to the colloidin technique described by Tumlison and McDaniel (1983).

Of the 1427 raccoon stomachs collected, 607 contained no food items or only debris consumed while in the trap, and are not included in this study. The 820 remaining stomachs were grouped according to region, sex, and age. Food items were grouped into six categories (acorns, non-acorns, terrestrial and aquatic vertebrates, insects, and other invertebrates). When more than one food item was found in a particular stomach, each item was considered to have equal value and, therefore, additively contributed to the diet (i.e., if there were four items in a stomach, each was considered to represent 1/4 of the whole or 0.25% of one).

Because over 70% of the stomachs collected were from raccoons of less than one year of age, ages have been reduced to individuals that are either less than one year of age (<1) or those that are over one year of age (>1). Table 1 shows these percentages for both age classes. The ratio of males to females is a little more even with males making up 55% and females being 45% of the total (Table 1).

In the stomachs of the two age classes that contained plant material, acorns made up 50% or more of the total, the only exception being the Delta region (Table 2). In all regions raccoons <1 year old consumed a higher percentage of acorns than animals >1 year, except in G.C.P. where the situation was reversed slightly. Stomachs from raccoons of the Delta reflected a higher usage of aquatic vertebrates than other regions, with animals >1 year using aquatic vertebrates more than the <1 year olds. Stomachs from the Ozarks and the G.C.P. reflecting the opposite by higher usage of terrestrial vertebrates by animals older than 1 year. The Ouachita region demonstrated almost even usage between terrestrial and aquatic vertebrates, with animals <1 year eating more terrestrials and animals >1 year eating more aquatic vertebrates. Insects and other invertebrates seemed to be consumed equally between the two age classes for all regions (Table 2).

### Table 1. Percentages for male and female raccoons and both age classes for the geographical regions of Arkansas.

<table>
<thead>
<tr>
<th>Region</th>
<th>Age</th>
<th>% in Group</th>
<th>Sex</th>
<th>% in Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delta</td>
<td>&lt;1</td>
<td>121</td>
<td>82</td>
<td>57</td>
</tr>
<tr>
<td></td>
<td>&gt;1</td>
<td>24</td>
<td>53</td>
<td>42</td>
</tr>
<tr>
<td></td>
<td></td>
<td>94</td>
<td>97</td>
<td>49</td>
</tr>
<tr>
<td></td>
<td></td>
<td>342</td>
<td>89</td>
<td>51</td>
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<td></td>
<td></td>
<td>189</td>
<td>134</td>
<td>54</td>
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<td>113</td>
<td>46</td>
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<tr>
<td></td>
<td></td>
<td>121</td>
<td>172</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>&gt;1</td>
<td>77</td>
<td>120</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td></td>
<td>619</td>
<td>455</td>
<td>55</td>
</tr>
<tr>
<td></td>
<td>&gt;1</td>
<td>201</td>
<td>565</td>
<td>45</td>
</tr>
</tbody>
</table>

### Table 2. Percent of food items consumed by raccoons of both age classes (< or > 1 year) for the four geographic regions of Arkansas.

<table>
<thead>
<tr>
<th>Region</th>
<th>Age</th>
<th>Acorns</th>
<th>Acorns Plants</th>
<th>Terrestrial Vertebr.</th>
<th>Aquatic Vertebr.</th>
<th>Insects</th>
<th>Other</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delta</td>
<td>&lt;1</td>
<td>36</td>
<td>85</td>
<td>15</td>
<td>27</td>
<td>7</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>&gt;1</td>
<td>21</td>
<td>42</td>
<td>63</td>
<td>17</td>
<td>38</td>
<td>55</td>
<td>13</td>
</tr>
<tr>
<td>Ozark</td>
<td>&lt;1</td>
<td>56</td>
<td>31</td>
<td>67</td>
<td>13</td>
<td>7</td>
<td>20</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>&gt;1</td>
<td>33</td>
<td>33</td>
<td>60</td>
<td>17</td>
<td>14</td>
<td>31</td>
<td>17</td>
</tr>
<tr>
<td>Ouachita</td>
<td>&lt;1</td>
<td>71</td>
<td>15</td>
<td>86</td>
<td>11</td>
<td>5</td>
<td>16</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>&gt;1</td>
<td>57</td>
<td>9</td>
<td>66</td>
<td>9</td>
<td>12</td>
<td>21</td>
<td>22</td>
</tr>
<tr>
<td>G.C.P.</td>
<td>&lt;1</td>
<td>68</td>
<td>21</td>
<td>89</td>
<td>17</td>
<td>8</td>
<td>25</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>&gt;1</td>
<td>68</td>
<td>21</td>
<td>89</td>
<td>17</td>
<td>8</td>
<td>25</td>
<td>26</td>
</tr>
</tbody>
</table>

Females in all regions demonstrate a higher usage of acorns than males. Raccoons from the Delta showed a preference for aquatic vertebrates, with raccoons from the Ozark and G.C.P. regions using terrestrial vertebrates to a higher degree. Ouachita males consumed more aquatic vertebrates and females more terrestrial vertebrates. Raccoons of both sexes did not demonstrate a preference for either insects or other invertebrates, except for females in the Ozarks and G.C.P. regions which consumed a greater proportion of insects than other invertebrates (Table 3). Raccoons generally use food in proportion to their availability as demonstrated Schoonover and Marshall (1951) and Johnson (1970). Results reflect what appears to be a degree of selectivity rather than a purely opportunistic feeding strategy.
Table 3. Percent of food items consumed by raccoons of both sexes for the four geographic regions of Arkansas.

<table>
<thead>
<tr>
<th>Region</th>
<th>Sex</th>
<th>Acorns</th>
<th>Acorns</th>
<th>Total Plants</th>
<th>Tres. Aqu.</th>
<th>Verte. Verte.</th>
<th>Total</th>
<th>Insects</th>
<th>Invert</th>
<th>Other</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delta</td>
<td>♂</td>
<td>31</td>
<td>40</td>
<td>80</td>
<td>20</td>
<td>29</td>
<td>49</td>
<td>7</td>
<td>6</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td></td>
<td>♀</td>
<td>71</td>
<td>13</td>
<td>84</td>
<td>10</td>
<td>29</td>
<td>39</td>
<td>10</td>
<td>11</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>Osage</td>
<td>♂</td>
<td>43</td>
<td>34</td>
<td>77</td>
<td>15</td>
<td>12</td>
<td>27</td>
<td>16</td>
<td>12</td>
<td>28</td>
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<tr>
<td></td>
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<td>84</td>
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<td>7</td>
<td>20</td>
<td>23</td>
<td>6</td>
<td>29</td>
<td></td>
</tr>
<tr>
<td>Ouachita</td>
<td>♂</td>
<td>67</td>
<td>17</td>
<td>84</td>
<td>7</td>
<td>10</td>
<td>17</td>
<td>11</td>
<td>13</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td></td>
<td>♀</td>
<td>69</td>
<td>9</td>
<td>78</td>
<td>14</td>
<td>3</td>
<td>17</td>
<td>14</td>
<td>10</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>G.C.P.</td>
<td>♀</td>
<td>66</td>
<td>25</td>
<td>91</td>
<td>13</td>
<td>5</td>
<td>18</td>
<td>20</td>
<td>19</td>
<td>39</td>
<td></td>
</tr>
</tbody>
</table>

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DEVELOPMENT OF A VARIABLE WAVELENGTH FLAME INFRARED EMISSION GAS CHROMATOGRAPHY DETECTOR

All matter above absolute zero, whether solid, liquid, or gas, continually absorbs and re-emits radiation due to the thermal agitation of its molecules, and is classified as a non-selective (blackbody or graybody) or selective radiator. Non-selective radiators emit a continuous spectral curve which has a maximum emittance at a specific wavelength which varies with temperature. Most heated solids behave as this kind of radiator. Selective radiators, such as hot gases and flames, emit radiation only over specific wavelength intervals depending on the molecular or atomic composition of the source (Fig. 1). Because the spectral lines or bands at certain wavelengths reveal the spectral characteristics of a selective radiator, they may be used for detection and analytical identification and are widely used in the determination of the functional components of organic compounds.

Different methods have been employed to determine the composition of compounds quantitatively or qualitatively. For example, the gravimetric procedure can be used for the determination of carbon and hydrogen (Ma and Ritter, 1975). Mass spectrometry procedures, in which charged particles are sorted according to their mass/charge ratio, give excellent information about molecular weight and structure. Nuclear Magnetic Resonance and the Infrared Absorption methods, such as FT, and dispersive, IR give significant organic functionality information (Willard, et al. 1988).

Combustion flames have been widely employed in detection systems for chromatography, either as spectroscopic sources as in the case of flame photometric detectors or as ionization cells in the case of flame ionization detection. However, a recently developed method using combustion flames is flame infrared emission (FIRE) detection. Carbon dioxide (CO2) and water vapor (H2O) IR emissions can be monitored in order to make carbon and hydrogen determinations. In the range of 2 to 5 µm, CO2 emits the strongest band centered at 4.4 µm, while H2O emits a band at 2.7 µm (Fig. 2) (Plyler, 1948). This use of IR emission has great potential usefulness since about 20% of the energy from a flame is emitted in this region compared to about 0.4% for the visible spectrum. For transparent flames such as the hydrogen/air flame, the visible emission is negligible and most of the radiated energy falls in the infrared region of the spectrum.

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Experiments demonstrating the analytical potential of using the 4.4 \( \mu \text{m} \) carbon dioxide emission band as a means of detecting organic compounds for both liquid and gas chromatography detection composed the initial work in this area (Hudson and Busch, 1987, 1988). These and other studies showed that the CO2 emission was useful quantitatively and could be used for analysis of some compounds that cannot be detected by FID (Hudson, et al., 1990). Non-chromatographic applications of FIRE include the determination of total inorganic carbon and volatile organics (Busch, et al., 1989) in water samples. The determination of chloride ion and available chlorine in aqueous samples has also been demonstrated (Kubala, et al., 1989) by using the intensity of the infrared emission due to the stretching vibration of HCl at 3.8 \( \mu \text{m} \). Other studies have indicated an HF band at 2.9 \( \mu \text{m} \), partially obscured by the water band emission.

A prototypical variable wavelength flame infrared emission gas chromatograph detector, consisting of a gas chromatograph (GC), burner, lead selenide (PbSe) detector, infrared filter, preamplifier electronics, chopper, reference electronics, lock-in amplifier and computer, is shown in Fig. 3. This FIRE unit is similar to others previously described, differing mainly in the use of a circularly variable filter and in the mechanical layout of the radiometer to allow adjustment of the wavelength. To summarize the methodology, a small amount of sample, typically 0.1 to 5 \( \mu \text{l} \), is injected into the GC where it is volatilized and then introduced into the center of the burner. As the sample flows into the flame zone or cell, it is combusted and the infrared emission energy is monitored through the 2.1 to 4.8 \( \mu \text{m} \) narrow bandpass circular variable infrared filter. Detection is accomplished via a PbSe photoconductive cell IR detector. This detector is mechanically chopped at 630 Hz, chosen since it is above the PbSe flicker noise threshold, and is amplified by a preamplifier circuit (Mofidi and Hudson, 1992). An Ithaco Model 3981 PC Board lock-in-amplifier demodulates the signal and a Zenith 80286 AT compatible computer provides instrument control, data storage, and processing, utilizing software written in house (Hudson and Hood, 1991.)
The variable wavelength FIRE detector has only been utilized with manual wavelength control at this time. However, the limited data collected indicate that the system can be used to monitor the carbon dioxide and water peaks at 4.4 and 2.7 μm with results similar to those seen using the single wavelength, fixed filter radiometers previously employed (Hudson, et al., 1990; Mofidi, et al., 1992). Fig. 4 shows the results obtained for the repetitive injection of one μl of hexane at the 4.4 μm CO₂ and 2.7 μm H₂O bands. Each injection was made with the filter adjusted in half degree increments to locate the maximum signal setting. Fig. 5 shows the signal obtained when the process was repeated for carbon tetrachloride. While these signals are noisier than those seen previously, note that the system has not been optimized. Fig. 6 shows the results obtained for the injection of 3 μl of carbon tetrachloride at the 3.8 μm HCl band. This band appears significantly noisier when compared to the CO₂ and H₂O bands. However, this data was taken using the same parameters as those used for carbon and hydrogen data collection, i.e., an oxidizing flame was used. Some previous studies indicate that a reducing flame, using only entrained air for flame support, is optimum for HCl emission (Kubala, 1989).

ACKNOWLEDGMENTS

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LITERATURE CITED


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ERRATUM

In the article "Preparation of a Series of N-Phenylamides of 5-Bromo-6-Chloronicotinic Acid" by Frank L. Setliff and Jody Z. Caldwell which appeared in Volume 45 (1991) of the Proceedings of the Arkansas Academy of Science, on page 93 the entire table headings (including the table number) of Tables 1 and 2 should be reversed.
The PROCEEDINGS OF THE ARKANSAS ACADEMY OF SCIENCE appears annually. It is the policy of the Arkansas Academy of Science that 1) at least one of the authors of a paper submitted for publication in the PROCEEDINGS must be a member of the Arkansas Academy of Science, 2) that only papers presented at the annual meeting are eligible for publication, and 3) that the manuscript is due at the time of presentation. In accordance with this policy, manuscripts submitted for publication should be given to the section chairman at the time the paper is being presented. Correspondence after this time should be directed to Dr. Harvey Barton, Editor-PAAS, Dept. Biological Sciences, Arkansas State University, State University, AR 72467.

Each submitted paper should contain results of original research, embody sound principles of scientific investigation, and present data in a concise yet clear manner. The COUNCIL OF BIOLOGY EDITORS' STYLE MANUAL, published by the American Institute of Biological Sciences, is an example of a convenient and widely consulted guide for scientific writers. Authors should strive for directness and lucidity, achieved by use of the active voice. Special attention should be given to consistency in tense, unambiguous reference of pronouns, and to logically placed modifiers. It is strongly recommended that all authors 1) inspect the existing format for feature articles and general notes in the PROCEEDINGS OF THE ARKANSAS ACADEMY OF SCIENCE and follow that format while drafting their submission, and 2) submit their manuscript to another qualified person for a friendly review to appraise it for clarity, brevity, grammar, and typographical errors.

Preparation of Manuscript

The author should submit two copies of the manuscript, tables, and figures. Manuscripts must be double spaced (preferably typed with a carbon-riboned typewriter on 8½ x 11 inch bond paper with one inch margins on all sides. Do not staple pages together. Do not hyphenate words on the right-hand margin; do not submit word processed copy printed with justified right-hand margins. Do not submit copy in italics; underline words to be set in italics. If joint-authored, designate which author is to receive correspondence and at what address.

An abstract summarizing in concrete terms the methods, findings and implications discussed in the body of the paper must accompany a feature article. The abstract should be completely self-explanatory.

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