Proceedings of the Arkansas Academy of Science - Volume 42 1988

Academy Editors

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PAST PRESIDENTS OF THE ARKANSAS ACADEMY OF SCIENCE

Charles Brookover, 1917
Dwight M. Moore, 1932-33, 64
Flora Haas, 1934
H. H. Hyman, 1935
L. B. Ham, 1936
W. C. Munn, 1937
M. J. McHenry, 1938
T. L. Smith, 1939
P. G. Horton, 1940
I. A. Willis, 1941-42
L. B. Roberts, 1943-44
Jeff Banks, 1945
H. L. Winburn, 1946-47
E. A. Provine, 1948
G. V. Robinette, 1949
John R. Totter, 1950
R. H. Austin, 1951

E. A. Spessard, 1952
Delbert Swartz, 1953
Z. V. Harvalik, 1954
M. Ruth Armstrong, 1955
W. W. Nedrow, 1956
Jack W. Sears, 1957
J. R. Mundie, 1958
C. E. Hoffman, 1959
N. D. Buffaloe, 1960
H. L. Bogan, 1961
Trumann McEver, 1962
Robert Shideler, 1963
L. F. Bailey, 1965
James H. Fribourgh, 1966
Howard Moore, 1967
John J. Chapman, 1968
Arthur Fry, 1969

M. L. Lawson, 1970
R. T. Kirkwood, 1971
George E. Templeton, 1972
E. B. Whitleake, 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 Sharrah, 1984
William L. Evans, 1985
Gary Heidt, 1986
Gary Tucker, 1987

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 COLLEGE, 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: JAMES H. PECK, Dept. of Biology, University of Arkansas at Little Rock, 2801 S. University Ave., Little Rock, AR 72204.

NEWSLETTER EDITOR: GARY TUCKER, Biological Sciences Dept., Arkansas Tech University, Russellville, AR 72801.

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

ASSOCIATE EDITORS:

AGRONOMY/PLANT PATHOLOGY: George E. TEMPLETON (UA)
AQUATIC/ENVIRONMENTAL: John K. Beadles (ASU)
BIOMEDICAL/PHYSIOLOGY: Earnest J. Peck (UAMS)
BOTANY: Carol J. Peck (UCA)

CHEMISTRY: Collis R. Geren (UA)
FISHERIES: Les Torrans (UAPB)
FORESTRY: Jimmie D. Yeiser (UAM)
GEOLOGY: John T. Thurmond (UALR)
PHYSICS: Mustafa Hemmati (ATU)

SCIENCE EDUCATION: Michael W. Rapp (UCA)
WILDLIFE MANAGEMENT: Gary A. Heidt (UALR)

PROCEEDINGS
ARKANSAS ACADEMY OF SCIENCE

Volume 42 1988

Gary Tucker
President

Horace Marvin
President-Elect

Dave Chittenden
Vice-President/President-Elect

Walt Godwin
Secretary

Robert Wiley
Treasurer

James Fribough
NAAS Delegate

Henry Robison
Historian

MINUTES OF THE SEVENTY-SECOND ANNUAL MEETING, 1-2 APRIL 1988

FIRST BUSINESS MEETING

Gary Tucker, President, called the meeting to order.

Dick Cohoon, Dean of Physical and Life Sciences, welcomed the Academy to the Annual Meeting. Cohoon made several announcements including mentioning the banquet and an open house at the mining institute on campus. He introduced Dr. Jim Ed McGehee, Vice President for Academic Affairs who welcomed the group to Arkansas Tech University.

Walter Godwin, Secretary, presented the minutes of the Seventy-First Annual Meeting. He stated that there were copies in the Proceedings and extras at the back of the room. He asked for any corrections to be presented in writing before the Second Business Meeting.

Bob Wiley, Treasurer, presented the Financial Report. He briefly discussed the report and indicated that the Academy is in good financial shape. He indicated that expenses were low for the previous year since no volume of the Proceedings was published. An Audit Committee consisting of Leon Richards (Chairman), and Eric Sundell will examine the report. A copy of the report follows.

ANNUAL FINANCIAL STATEMENT

SUMMARY

(13 March 1987 to 17 March 1988)

Balance Approved by Audit on 4 April 1987 $10,495.45

Total Income (Page 2) 6741.60
Total Expenses (Page 3) 2124.21
Balance for the Year 4617.39

TOTAL FUNDS AS OF 17 MARCH 1988 $15,112.04

DISTRIBUTION OF ACCOUNTS

Interest Bearing Checking Account (Union Bank and Trust Co., Monticello, AR) 9160.03
Certificates of Deposit:
Dwight Moore Endowment (1st National Bank of Conway - No. 78794 - 7% Interest) 1077.25
Life Membership Endowment (Heritage Federal Savings and Loan - Monticello - No. 82440 - 7% Interest) 4805.56
Arkansas Academy of Science Endowment - Matured at $2760.92 on 18 February 1988 - A new CC to be purchased soon. Monies currently in Interest bearing checking account. 15,112.04

INCOME: 15 March 1987 to 17 March 1988

1. ANNUAL MEETING: RIVERFRONT HILTON, NLR. 768.98
   3-4 APRIL 1987

2. INDIVIDUAL MEMBERSHIPS
   a. Regular (19) 2280.00
   b. Sustaining (2) 920.00
   c. Sponsoring (9) 325.00
   d. Life (20) 680.00
   e. Associate (5) 25.00

   Total 3450.00 3450.00

3. INSTITUTIONAL MEMBERSHIPS (4)

4. PROCEEDINGS, LIBRARY SUBSCRIPTIONS 78.00

5. BIOTA RECEIPTS 130.00

6. INTEREST
   a. Interest Bearing Checking Account 267.87
   b. Dwight Moore Endowment 76.40
   c. AIR Endowment 214.46
   d. Life Membership Endowment 224.69

   Total 817.62 817.62

7. ENDOWMENTS 700.00

8. MISCELLANEOUS 70.00

TOTAL INCOME 6741.60

EXPENSES: 15 March 1987 to 17 March 1988

1. AWARDS
   a. Kyle J. Welz (#227) 35.00
   b. Beth A. Lowery (#223) 10.00
   c. Robert M. Schuckman (#229) 25.00
   d. Hal Palmer (#230) 50.00
   e. Belinda Paybol (#231) 50.00
   f. Arkansas Science Talent Search (#232) 20.00
   g. Arkansas Junior Academy of Science (#233) 200.00
   h. Arkansas Science Fair Association (#234) 200.00

   Total 610.00 610.00

2. MEETING EXPENSES (RIVERFRONT HILTON) (#502) 191.28

3. OPERATING EXPENSES
   a. Secretary's Office (#224, #236) 250.00
   b. Treasurer's Office (#501, #504) 168.66

4. OPERATING EXPENSES
   a. Secretary's Office (#224, #236) 250.00
   b. Treasurer's Office (#501, #504) 168.66

Proceedings Arkansas Academy of Science, Vol. 42, 1988
4. NEWSLETTER
a. Gloriare Printing & Office Supply ($308.52) 569.74
b. UALR Biology Department ($506.50) 126.11

c. 120.00

5. DUES - National Association of Academies of Science ($509)

6. BIUT EXPENSES ($227)

7. MISCELLANEOUS ($226.55)

TOTAL EXPENSES

NAME: DWIGHT MOORE ENDOWMENT
PLACE: 1st National Bank of Conway
NUMBER: 7016
AMOUNT: $177.28
DATE PURCHASED: 2 January 1987
INTEREST RATE: 7% (interest paid to AAS semiannually)
DURATION: 12 Months
MATURITY DATE: 2 January 1990

The funds for this CD are derived from money contributed by members and friends of the AAS in memory of Dwight Missouri Moore 1891-1985. It is intended that the interest generated from this capital be used to give awards in the name of the honoree. There is no obligation to use all of the interest, nor that the fund can grow. No provision has as yet been made as to what the awards might be other than they would be in education and would honor outstanding work in the sciences.

NAME: ARKANSAS ACADEMY OF SCIENCE ENDOWMENT
PLACE: 1st State Bank and Trust (Conway)
NUMBER: 60177-69-4
AMOUNT: $405.62
DATE PURCHASED: 16 February 1985
INTEREST RATE: 10% (interest compounded quarterly)
DURATION: 36 Months
MATURITY DATE: 16 February 1988

The majority of funds in this CD are unrestricted as to their use. Some or all of the funds within the Arkansas Academy of Science Endowment were donated with restrictions as to their use within the following categories: Research Grants, Tuitions, Scholarships, and Other.

NAME: LIFE MEMBERSHIP ENDOWMENT
PLACE: Heritage Federal Savings and Loan Assn. (Monticello)
NUMBER: 60240
AMOUNT: $409.95
DATE PURCHASED: 11 March 1988
INTEREST RATE: 7% (interest compounded quarterly)
DURATION: 12 months
MATURITY DATE: 11 March 1989

The funds for this CD are derived from money paid by members of the AAS for Life Membership ($200.00). It is thought that these monies should be kept separate from other monies and perhaps earmarked for some special purpose. An individual becomes life members the no longer pay annual dues. Thus it may be desirable to annually remove from this endowment an amount equal to the number of life members X the annual dues and deposit it in the checking account. The additional interest earned would be used for other purposes (education and research). Life members would thus be contributing to the Arkansas Academy of Science long after they have become inactive. Life Memberships would have value not only for the life of the individual, but also for the life of the Arkansas Academy of Science.

(Note: When CD's mature additional monies collected for that particular CD since investment are added to the maturity amount and reinvested in a new CD.)

Respectfully Submitted,

Robert W. Wiley, AAS Treasurer

Annual Meeting: 1-2 April 1988
Arkansas Tech University, Russellville, AR

Jim Peck, Editor of the Proceedings, indicated that volume 41 of the Proceedings was available. He stated that this volume contained 20 articles and 20 notes of great diversity. He also reminded section chairs be sure to collect papers at the sessions and to turn in those papers. He also indicated that numerous assistant editors were now being used. He mentioned that Volume 40 should go to the printer soon. He presented the following motion:

Mr. President, I move that the Academy appropriate $500.00 for editorial assistance and $120.00 for travel for preparation of Volume 42 of the Proceedings for the year 1988.

The motion was seconded and will be voted on at the Second Business Meeting.

John Rickett, Editor of the Newsletter, indicated he will be retiring after the Second Business meeting. He thanked the members for their support. He stated that the Executive Committee has voted to continue the "membership drive" with the additional copies of the Fall Newsletter. He presented the following motion:

Mr. President, I move that the Arkansas Academy of Science commit $750.00 to the production and mailing of the two Newsletter issues for the Academic Year 1988-89.

The motion was seconded and will be voted on at the Second Business Meeting.

Mike Rapp, Director of the Arkansas Science Fair Association, reported on the Science Fair. He stated that there were seven regional fairs and the state fair held this year. He thanked the Academy for both judging assistance and financial support. He presented the following motion:

Mr. President, I move that the Arkansas Academy of Science provide $200.00 support to the Arkansas Science Fair Association for distribution among the seven regional science fairs and the state science fair.

The motion was seconded and will be voted on at the Second Business Meeting.

Mike Rapp reported for Paul Kruse concerning the Arkansas Junior Academy of Science. He described the activities of the Junior Academy and mentioned that the Junior Academy now has an Executive Committee. He presented the following motion:

Mr. President, I move that the Arkansas Academy of Science provide $250.00 support to the Arkansas Junior Academy of Science.

The motion was seconded and will be voted on at the Second Business Meeting.

John Peck, Director of the Arkansas Science Talent Search, reported on the results of this year's Talent Search. His report follows.

Following is the list of high school seniors who placed in the 37th Annual Arkansas Science Talent Search 1987-88, held in conjunction with the 47th Annual Westinghouse Science Talent Search.

First Place
David Pearce Gillson
7500 Dover Place
Fort Smith, AR 72903
Improving Air Flow Uniformity in a Lumber Dryer
Fort Smith Christian School
Sponsored by Mr. John Deaton and Mr. Charles Besancon

Second Place
Jeffery Chi Wei Koay
P.O. Box 1842
Pine Bluff, AR 71601
Newcomb's Paradox and Its Implications on Free Will
Pine Bluff High School
Sponsored by Mr. Jerrel Boast

Third Place
Dionne Leigh Baxter
Route 1, Box 699R
Batesville, AR 72501
Is Curia Creek Really Polluted?
Batesville High School
Sponsored by Mr. Paul Reynolds
He presented the following motion:

Mr. President, I move that the Arkansas Academy of Science provide up to $120.00 to the Arkansas Science Talent Search for the purpose of plaques for the three award winners for 1987-88.

The motion was seconded and will be voted on at the Second Business Meeting.

President Tucker reported for Tom Palko, Director of the Arkansas Junior Science and Humanities Symposium. He stated that the Symposium went very well this year with good participation.

President Tucker reported that Horace Marvin, President-Elect, had resigned due to health reasons. The Executive Committee has moved Dave Chittenden, Vice President, to President-Elect. Tucker expressed regret that Marvin had found it necessary to resign and also expressed appreciation for his service this year.

Glynn Turnipseed, Chairman of the Nominating Committee, presented the nominees for Vice President and President-Elect. The nominees for Vice President were Peggy Rae Dorris, Henderson State University, and Arthur Johnson, Hendrix College. The nominees for Vice President were Robert Watson, UALR, and George Harp, Arkansas State University.

Leo Paulissen reported on the Biota Survey. Combined checklists are available for $10.

President Tucker announced that the Resolutions Committee will consist of Bill Shepherd and Rick McDaniel.

President Tucker announced that the location of the 1989 meeting will be the University of Arkansas for Medical Sciences and that the location of the 1990 Meeting will be Arkansas State University. There is also a tentative invitation from the University of Arkansas at Fayetteville for 1991.

Robbin Anderson, Chairman of the Science Education Committee, reported that there would be a committee meeting later in the afternoon.

President Tucker asked for old business and none was presented.

President Tucker asked for new business. Dick Speairs expressed two ideas for Academy consideration. First, he asked if there were any representatives from 2-year institutions present. There were none. He suggested that the Executive Committee should try to generate more involvement from 2-year institutions. Secondly, he suggested that the Academy should have a representative at meeting of the Board of Higher Education. No action was taken on these suggestions.

President Tucker encouraged section chairs to keep their sections on time and to be sure to pick up papers for publication. He also stated that judges were needed for the undergraduate papers and asked for volunteers.

President Tucker adjourned the First Business Meeting.

SECOND BUSINESS MEETING

Gary Tucker, President, called the meeting to order.

Walter Godwin, Secretary, moved the approval of the minutes of the Seventieth Annual Meeting as distributed with no corrections. The motion was seconded and passed.

President Tucker repeated his statement from the first meeting that Horace Marvin had resigned and that Dave Chittenden had been moved from Vice President to President-Elect by the Executive Committee. He also repeated the report from Glynn Turnipseed, Chairman of the Nominating Committee, indicating that the nominees for Vice President were Peggy Rae Dorris, Henderson State University, and Arthur Johnson, Hendrix College and that the nominees for Vice President were Robert Watson, UALR, and George Harp, Arkansas State University. Arthur Johnson asked that his name be removed from consideration and nominated Richard Speairs. The nomination was seconded. It was moved, seconded and passed that the nominations cease. Ballots were distributed and collected. A report of the results appears later in these minutes.

Robert Wiley, Treasurer, indicated that the additional copies of the Treasurer's Report were available and discussed it briefly. He moved that the Treasurer's Report be approved. The motion was seconded. Edward Richards, Chairman of the Audit Committee, presented the following report from the Audit Committee.

The Audit Committee on reviewing the Treasurer's Financial Statement, books and records for 1987-88 find everything to be in order and correct. We recommend the Treasurer's Report be accepted and extend to Dr. Robert Wiley our thanks and congratulations for excellent and accurate record keeping.

Respectfully submitted,
Edward L. Richards, Chairman
Eric Sundell

It was moved and seconded to accept the report of the Audit Committee. The motion passed. The initial motion concerning acceptance of the Treasurer's Report passed.

The motion presented at the First Business Meeting by Jim Peck, Editor of the Proceedings, to allocate $500 for editorial assistance and $120 for travel for the Proceedings for next year was passed.

The motion presented at the First Business Meeting by John Rickett, Editor of the Newsletter, to allocate $750 for the Newsletter for next year was passed.

The motion presented at the First Business Meeting by Mike Rapp, Director of the Arkansas Science Fair Association, to provide $200 support to the Arkansas Science Fair Association for next year was passed.

The motion presented at the First Business Meeting by Mike Rapp for Paul Krause, Director of the Arkansas Junior Academy of Science, to provide $250 support to the Arkansas Junior Academy of Science for next year was passed.

The motion presented at the First Business Meeting by John Peck, Director of the Arkansas Science Talent Search, to provide up to $120 to the Arkansas Science Talent Search for the purpose of plaques for the three award winners for 1987-88 was passed.

Henry Robinson, Historian, reported that this was the 72nd Annual Meeting and that it was the fourth time the Academy had been hosted by the Arkansas Tech University.

Ed Bacon reported for the Development Committee. He mentioned the Development Brochure which had been developed and distributed the past year. He reported that there was $5000 in the general Endowment Fund and $1100 in the Dwight Moore Endowment Fund. He thanked members for their support and encouraged additional contributions. He stated that development efforts would continue.

Leo Paulissen reported on the Biota Survey. A compilation of about 50 checklists is now available.

Robbin Anderson, Chairman of the Science Education Committee, mentioned increasing needs in the education area and especially in
teacher education. He stated that the committee had no specific recommendations but that it will keep in contact with the Academy.

President Tucker reported on the undergraduate awards. He reported that the awards had been won by:

Physical Sciences:
J.G. Ross - UCA
Measurements of the Drag on Spheres Falling Through the Air.

Life Sciences: tie
Luke Eggering - Arkansas Tech University
Autumn Diets of White-Tailed Deer in Arkansas
Yvette Randle - UAPB
Strongyloides stercoralis: Immunobiological Studies of an Unusual Worm.

Dick Spears reexpressed two ideas for Academy consideration. First, he asked if there were any representatives from 2-year institutions present. There were none. He stated that there are 10 such schools in the state, three of which are affiliated with 4-year schools. He suggested that a project be undertaken to encourage participation from these schools. Secondly, he suggested that the Academy should have a representative at meeting of the Board of Higher Education since the board directs education in the state. It was decided that the Executive Committee should consider these proposals.

Dave Saugey stated that a preliminary list of herptiles of the State Parks had been completed. Copies of this list are available.

President Tucker announced the results of the election. Robert Watson was elected Vice President and Dick Spears was elected President-Elect.

Bill Shepherd, Chairman of the Resolutions Committee, moved the adoption of the following resolution.

Be it resolved:

The members of the Arkansas Academy of Science express their gratitude to Arkansas Tech University for hosting the Academy's 1988 meeting. In particular, the Academy thanks Richard Cohoon, Dean of Physical and Life Sciences, who was in charge of local arrangements, and the entire faculty of Cohoon's school, who assisted in various ways. Appreciation is expressed to all who helped provide comfortable and convenient facilities and an excellent banquet. Dr. Warren H. Wagner's outstanding banquet address on endangered species was a highlight of the meeting, and the Academy is grateful to the ATU office of Academic Affairs for underwriting the cost of bringing him to Russellville.

The Academy appreciates the work of the various section chairmen and recognizes the important role they played in the conduct of the meeting. They are as follows:

O. D. Smith (Agronomy/Forestry), Harlan McMillan (Aquatic/Environmental I), John Martin (Biomedical/Microbiology I), Gerald Hutchinson (Botany), Robert Allen (Chemistry I), Victor Vere (Geology/Earth Science), Robbin Anderson (Science Education I & II), Glyn Turnipseed (Vertebrate Zoology I), Bruce Shackelford (Aquatic/Environmental II), Scott Kirkconnel (Biomedical/Microbiology II), William Trigg (Chemistry II), Raymond Couser (Invertebrate Zoology), Mostafa Hemmati (Physics/Mathematics), and Tom Nelson (Vertebrate Zoology II).

The Academy expresses gratitude to the various directors of the science youth activities supported by the Academy:

Robbin Anderson, the Science Education Committee; Mike Rapp, Director of the Arkansas State Science Fair; Tom Palko, Director of the Junior Science and Humanities Symposium; Paul Krause, the Arkansas Junior Academy of Science; John Peck, Director of the Arkansas Science Talent Search; Leo Paulissen, the Biota Committee; and Ed Bacon, the Development Committee.

The Academy is only as successful as its leadership in planning, working and directing the various activities. To Gary Tucker, President; David Chittenden, President-Elect; Walter Godwin, Secretary; Robert Wiley, Treasurer; Ed Bacon, Past-President; Jim Peck, Proceedings Editor; John Rickett, outgoing Newsletter Editor; and Henry Robison, Historian, the Academy expresses gratitude and thanks for an excellent year.

The Academy expresses thanks and encouragement to continue in Advanced Scientific, Inc., the Arkansas Geological Commission, Jacobs Instrument Co., the Ozark Interpretive Association, S & S Scientific Co., and Sargent-Welch Scientific Co. for their exhibition booths at the meeting.

The Academy recognizes with appreciation the work of Ed Bacon, Rose McConnell, and Mike Rapp for their efforts on the Student Awards Committee, Glyn Turnipseed, William Evans, and Henry Robison for their work on the Nominating Committee, and Victor Vere and William Guest as tellers.

The Academy is appreciative for design and art work to the ATU Art Department, program cover; Jim Edson, plaques; and Calvin Cotton, calligraphy on student awards.

Finally, the Academy expresses fond remembrance and regret in the deaths of two of its members, Maxine Clark and Delzie Demaree.

The motion was seconded and passed.

President Tucker announced that there would be a group picture taken after adjournment of the business meeting.

President Tucker announced that meetings have been scheduled for the next three years. The Academy will meet at the University of Arkansas for Medical Sciences in 1989, at Arkansas State University in 1990, and tentatively at the University of Arkansas at Fayetteville in 1991.

President Tucker expressed appreciation for the help he has received in the past year.

President Tucker presented a plaque to John Rickett in recognition of six years service as Newsletter Editor.

President Tucker called on President-Elect Dave Chittenden and passed the gavel to him.

President Chittenden invited all members to UAMS for next year's meeting.

President Chittenden presented Past-President Tucker with a plaque in recognition of his year of service.

President Chittenden asked that a representative from each institution or organization pick up copies of the Proceedings for those not in attendance.

It was moved, seconded and passed to adjourn the meeting.

Respectfully submitted,
Walter E. Godwin
Secretary
### Regular

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<tr>
<th>Name</th>
<th>Organization</th>
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<td>Richard A. Konozuk</td>
<td>University of Arkansas for Medical Sciences</td>
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<td>Kendall A. Koger</td>
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**Note:** The list includes names of individuals associated with universities and organizations located in various cities across Arkansas, such as Little Rock, Monticello, Pine Bluff, and others. The affiliations cover a wide range of scientific disciplines and institutions.
Proceedings Arkansas Academy of Science, Vol. 42, 1988

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PROGRAM
Arkansas Academy of Science

Seventy-Second Annual Meeting
ARKANSAS TECH UNIVERSITY
Russellville, Arkansas

Meeting concurrently with sessions of
The Collegiate Academy of Science

Friday, 1 April, 1988

SENIOR AND COLLEGIATE ACADEMIES -- Registration
SENIOR ACADEMY -- Executive Board Meeting
SENIOR ACADEMY -- First General Business Meeting
Lunch
SENIOR AND COLLEGIATE ACADEMIES: Registration
SENIOR AND COLLEGIATE ACADEMIES: Papers [Concurrent Sessions]:
- Agronomy-Forestry
- Aquatic and Environmental I
- Biomedical-Microbiological I
- Botany
- Chemistry I
- Geology-Earth Science
- Science Education I
- Vertebrate Zoology I
SENIOR AND COLLEGIATE ACADEMIES -- Banquet
POST BANQUET SPEAKER -- Dr. Warren H. Wagner, Jr.
University of Michigan
Ann Arbor, MI

Saturday, 2 April, 1988

SENIOR AND COLLEGIATE ACADEMIES -- Registration
SENIOR AND COLLEGIATE ACADEMIES -- Papers [Concurrent Sessions]:
- Aquatic and Environmental II
- Biomedical-Microbiological II
- Chemistry II
- Invertebrate Zoology
- Physics-Mathematics
- Vertebrate Zoology II
ARKANSAS SCIENCE TALENT SEARCH
SENIOR ACADEMY -- Second General Business Meeting
SECTION PROGRAMS

AGRONOMY - FORESTRY
Session Chairperson: O. D. Smith (Timber Staff Officer, Ozark-St. Francis National Forests, Russellville, AR)

ADVENTURES IN FORESTRY - THE TAIWAN CONNECTION.

FORESTRY ON THE ISLAND OF TAIWAN, REPUBLIC OF CHINA - THE STATE OF THE ART.

ARKANSAS' FORESTS: YESTERDAY, TODAY, AND TOMORROW.

A FOUR YEAR ANALYSIS OF WILDFIRES IN SOUTHEASTERN ARKANSAS.

INFLUENCE OF NITROGEN FERTILITY ON MILLING YIELD OF RICE (Oryza sativa).
R. H. Dilday, USDA-ARS, Box 287, Stuttgart, AR 72160.

IMPACTS OF SILVICULTURAL ALTERNATIVES ON NUTRIENT EXPORT VIA STREAMFLOW IN THE OUACHITA MOUNTAINS.
R. S. Beasley, E. L. Miller, and E. R. Lawson. Department of Forest Resources, UAM, Monticello, AR 71655; Dept. of Forestry, OSU, Stillwater, OK 74075; Forest Hydrology Lab, US Forest Service, Oxford, MS 38655.

STANDARD AND SEMIDWARF RICE (Oryza sativa) CULTIVARS AND THE ASSOCIATION OF PLANT HEIGHT, SEEDLING VIGOR, AND MESOCOTYL/COLEOPTILE ELONGATION.

SEEDLING GROWTH RESPONSE IN A GREENHOUSE TO FOUR RATES OF OLD AND NEW PAPER MILL SLUDGE.
J. L. Yeiser, Department of Forest Resources, UAM, Monticello, AR 72655.

HERBICIDE TREATMENTS FOR CONTAINER-GROWN SEEDLINGS IN PROGENY TESTS.
J. L. Yeiser (UAM), J. W. Boyd (Extension), and D. J. Reed (UAM). Dept. of Forest Resources, UAM, Monticello, AR 72655; Arkansas Cooperative Extension Service, Little Rock, AR 72203.

SURVIVAL AND GROWTH TWO YEARS AFTER CONTROL OF HERBACEOUS COMPETITORS IN NEWLY PLANTED SEEDLINGS OF Loblolly PINE.

THE EFFECTS OF ANTHROPOGENIC STRESSES ON SOIL WATER CHEMISTRY OF SOUTHERN PINE FORESTS.
G. L. Wheeler, T. T. Ku, and R. J. Colvin; Dept. of Horticulture and Forestry, UA, Fayetteville, AR 72701; Dept. of Forestry Resources, UAM, Monticello, AR 71655; and SW Research and Extension Center, UA, Hope, AR 72801.

AQUATIC - ENVIRONMENTAL I
Session Chairperson: Dr. Harlan McMillan (Biology, ATU)

PCB CONTAMINATION IN LAKE PINE BLUFF.
Bruce Shackleford, Arkansas Department of Pollution Control & Ecology, 8001 National Drive, Little Rock, AR 72209.

DISTRIBUTION AND HABITAT OF DARTERS AS FOUND IN REPRESENTATIVE STREAMS OF CLARK COUNTY, ARKANSAS.
Thomas Brett Hobb, HSU, Arkadelphia, AR 71923.

RAPID BIOASSESSMENTS OF MACROINVERTEBRATE COMMUNITIES IN ARKANSAS STREAMS.
Bruce Shackleford, Arkansas Dept. of Pollution Control and Ecology, 8001 National Drive, Little Rock, AR 72209.

A PRACTICAL WATER SAMPLER.
Richard S. Mitchell and Edward L. Richards, Depts. of Chemistry and Biological Sciences, ASU, State University, AR 72467.

PHYTOTOXICITY OF SOIL RESIDUES OF JP-4 AVIATION FUEL.
Richard H. Brown, Biology Department, OBU, Box 3666, Arkadelphia, AR 71923.

CATFISH (Ictalurus punctatus) AQUACULTURE AND OFF-FLAVOR RELATED TO BLUE-GREENS.
Richard S. Mitchell and Edward L. Richards, Depts. of Chemistry and Biological Sciences, ASU, State University, AR 72467.

BIOLOGICAL RESPONSE TO HABITAT ALTERATION IN A SMALL OZARK STREAM.
Danny J. Ebert and Stephen P. Filipiek. U.S. Forest Service, 605 W. Main, Russellville, AR 72801; and Arkansas Game and Fish Commission, #2 Natural Resources Drive, Little Rock, AR 72201.

BIOMEDICAL - MICROBIOLOGY I
Session Chairperson: Dr. John Martin (Chemistry, ATU)

PLASMA CORTICOSTERONE CONCENTRATION DECREASES WITH INCREASE OF BODY TEMPERATURE IN BACTERIAL LIPOPOLYSACCHARIDE-INJECTED RABBITS.
Stanley N. David and Lawrence W. Hinck. Department of Biological Sciences, ASU, State University, AR 72467.

THE EFFECT OF METRONIDAZOLE ON THE MURINE IMMUNE RESPONSE TO PNEUMOCOCCAL POLYSACCHARIDE AND THE EFFECT OF METRONIDAZOLE ON THE MURINE IMMUNE RESPONSE TO PNEUMOCOCCAL POLYSACCHARIDE.

ATTEMPTED SYNTHESIS OF ENKEPHALIN ANALOGUES AS OPIATE RECEPTOR LABELS.
Denny L. Latiss (UAMS), John Moix (UAMS), and Eric Pierce (SAU). College of Pharmacy, UAMS, Little Rock, AR 72204; and SAU, Magnolia, AR 71753.

MALARIAL DEHYDROGENASE KINETICS OF AN ANAEROBIC VERTEBRATE.

Strongyloides stercoralis: IMMUNOBIOLOGICAL STUDIES OF AN UNUSUAL WORM.
Yvette Randle and Robert Genta. Dept. of Biology, UAPB, Pine Bluff, AR 71601; Laboratory for Infectious Diseases, Cincinnati Veterans Hospital, Cincinnati, OH 45219.
TO RIGHT OF WAY.

HUBERT W. WINTER AND JAMES H. PECK

HABITATS OF GEOCARPON MINIMUM MACKENZIE IN ARKANSAS.

WENDY T. MURPHY AND JIM STOEGER

EDWIN L. MILLER AND GARY TUCKER

FURTHER STUDIES OF A HEAT STABLE NUCLEAR CYCLIC-GMP AND CYCLIC-AMP PHOSPHODIESTERASE FROM THE PLASMODIUM OF PHYSARUM FLAVICUM.

C. KAY HOLTZMAN (UALR), JUDITH A. BEAN (UCA), AND THOMAS J. LYNCH (UALR). DEPT. OF BIOLOGY, UALR, LITTLE ROCK, AR 72204; AND DEPT. OF BIOLOGY, UCA, CONWAY, AR 72032.

DEVELOPMENT OF MONOClonAL ANTIBODIES TO THE MUCOID EXOPOLYSACCHARIDE OF PSEUDOMonas AERUGINOSA.

JOHN T. STINE, JAMES M. SAUNDERS, AND R. MARK WOOTEN. DEPT. OF BOTANY AND MICROBIOLOGY, UA, FAYETTEVILLE, AR 72701.

ANTIMICROBIAL PROPERTIES FROM LAND SNAIL EGGS.

WINIFRED FRASER, ARKANSAS COLLEGE, BATESVILLE, AR 72501.

BOTANY

SESSION CHAIRPERSON: DR. GERALD HUTCHINSON

MINING AND MINERAL RESOURCES RESEARCH INSTITUTE, ATU

GIBBERELLIN FUNCTION IN CASTOR BEAN IS ASSOCIATED WITH CHANGES IN TISSUE SENSITIVITY.

JAMES G. TAYLOR AND JOHN S. CHOINSKI, JR. DEPT. OF BIOLOGY, UCA, CONWAY, AR 72032.

SPECIES BIOLOGY OF LINDERA MELISSIFOLIA, PONDBERRY, A FEDERALLY LISTED SPECIES, IN NORTHEAST ARKANSAS.

ROBERT D. WRIGHT, DEPT. OF BIOLOGY, UCA, CONWAY, AR 72032.

A SURVEY OF THE VASCULAR PLANTS OF CARROLL COUNTY, ARKANSAS.

MICHAEL E. MURPHY, DEPT. OF BIOLOGICAL SCIENCES, ASU, STATE UNIVERSITY, AR 72467.

IDENTIFICATION, SURVEY, AND EVALUATION OF POTENTIAL HABITATS OF GEOCARPON MINIMUM MACKENZIE IN ARKANSAS.


SELECTED SPECIES OF NATIVE PLANTS FOR USE ON HIGHWAY RIGHT OF WAY.

DON CULWELL AND WENDY WELCH, DEPT. OF BIOLOGY, UCA, CONWAY, AR 72032; AND ARKANSAS HIGHWAY AND TRAFFIC DEPARTMENT, ENVIRONMENTAL DIVISION, BOX 2261, LITTLE ROCK, AR 72203.

LITERATURE TO ARKANSAS FIELD BOTANY.

JAMES H. PECK AND CAROL J. PECK. DEPARTMENT OF BIOLOGY, UALR, LITTLE ROCK, AR 72204.


GARY TUCKER, BIOLOGICAL SCIENCES DEPT., ATU, RUSSELLVILLE, AR 72801.
THE SYNTHESE AND CHARACTERIZATION OF ANTIENO-PLASTIC AND SUPEROXIDE DISMUTASE-MIMETIC MANGANESE(II) COMPLEXES.

FLUORESCENCE-FREE RAMAN SPECTROSCOPY.
Skip Williams. Chemistry Dept. UALR, Little Rock, AR 72204.

GEOLOGY - EARTH SCIENCES
Session Chairperson: Dr. Victor Vere (Geology, ATU)

David M. Chittenden II. Chemistry Dept., ASU, State University, AR 72467.

THE WILCOX GROUP OF UNION COUNTY, ARKANSAS: STRATIGRAPHY AND GEOHYDROLOGIC APPLICATIONS.
Lesli J. Wood. Dept. of Geology, UA, Fayetteville, AR 72701.

GAMMA RAY MEASUREMENTS IN HOT SPRINGS NATIONAL PARK ARKANSAS.

COMPARISON OF EARTHQUAKE MITIGATION IN SMALL COMMUNITIES VS. URBAN CENTERS.
David L. Yooburg. Dept. of Chemistry, ASU, State University, AR 72467.

TREETHROW AS A MASS WASTING PROCESS IN THE BOSTON MOUNTAINS OF NORTHERN FRANKLIN COUNTY, ARKANSAS.
John D. Hall. Dept. of Geography, UA, Fayetteville, AR 72701.

EVOILUTION OF THE MISSISSIPPI RIVER FLOOD PLAIN NEAR BLYTHEVILLE, ARKANSAS.
M. J. Guccione. Dept. of Geology, UA, Fayetteville, AR 72701.

SCIENCE EDUCATION I
Session Chairperson: Dr. Robbin Anderson (Chemistry, UA)

UNDERGRADUATE RESEARCH AS SCIENCE EDUCATION.
Frank Millett, Dept. of Chemistry, UA, Fayetteville, AR 72702; Thomas J. Lynch, Dept. of Biology, UALR, Little Rock, AR 72204; Thomas E. Goodwin, Dept. of Chemistry, Hendrix College, Conway, AR 72032.

VERTEBRATE ZOOLOGY I
Session Chairperson: Dr. Glyn Tunnipseed (Biology, ATU)

FOOD HABITS OF THE NINE-BANDED ARMADILLO (Dasypus novemcinctus) IN SOUTHWESTERN ARKANSAS.
Robert S. Sikes (MSU), Gary A. Heidt (UALR), Joni L. Matthews, (UALR), and Douglas Eldro (UALR). Dept. of Biology, MSU, Memphis, TN 38152; and Dept. of Biology, UALR, Little Rock, AR 72204.

USE OF FOREST OPENINGS BY WILD TURKEYS ON THE OZARK NATIONAL FOREST.
Thomas A. Nelson (ATU), Lowell Aberson (ATU), and Gary Harnum (USFS). Biological Sciences Dept., ATU, Russellville, AR 72801; and USFS, Ozark-St. Francis National Forests, Russellville, AR 72801.

THE BATS OF HOT SPRINGS NATIONAL PARK.
David A. Saugey (USFS), Dianne G. Saugey (USFS), Gary A. Heidt, (UALR), and Darrell R. Heath (UALR). USFS, Ouachita National Forest, Hot Springs, AR 72902; Dept. of Biology, UALR, Little Rock, AR 72204.

AUTUMN DIETS OF WHITE-TAILED DEER IN ARKANSAS.
Thomas A. Nelson (ATU), Luke Eggering (ATU), and Danny Adams (IPC). Biological Sciences Dept., ATU, Russellville, AR 72801; and International Paper Company, Arkadelphia, AR 71923.

EFFECT OF FIRE ON POPULATIONS OF THE PRAIRIE VOLE (Microtus ochrogaster) ON THE GRAND PRAIRIE IN CENTRAL ARKANSAS.
Mark Kirchner, Belinda Raybon, and Gary Heidt. Dept. of Biology, UALR, Little Rock, AR 72204.

AN ANALYSIS OF BARN OWL PELLETS FROM A SINGLE LOCATION.
T. W. Steward (ATU), J. D. Wihide (ASU), V. R. McDaniel (ASU), and Dan England (SAU). Dept. of Biological Sciences, ASU, State University, AR 72467; Biology Dept., SAU, Magnolia, AR 71753.

DISTRIBUTION AND ASPECTS OF REPRODUCTION AND NATURAL HISTORY OF THE BRAZILIAN FREE-TAIL BAT, Tadarida brasiliensis cynocephala, IN ARKANSAS.
David A. Saugey (USFS), Tim W. Steward (ASU), Daniel R. England (SAU), V. R. McDaniel (ASU), and Gary A. Heidt (UALR), U. S. Forest Service, Ouachita National Forest, Hot Springs, AR 71902; Dept. of Biological Sciences, ASU, State University, AR 72467; Biology Dept., SAU, Magnolia, AR 71753; and Dept. of Biology, UALR, Little Rock, AR 72204.

REPRODUCTIVE CHARACTERISTICS OF SOUTH FLORIDA Sternotherus odoratus AND Kinosternon baurii TESTUDINIDAE.
Walter E. Meshaka, Dept. of Biological Sciences, ASU, State University, AR 72467.

EGGTOOTH DEVELOPMENT AND MORPHOLOGY IN THE SIX-LINED RACERUNNER, Cnemidophorus sexlineatus (SAURIA: TESTUDINIDAE) USING SCANNING ELECTRON MICROSCOPY.
Stanley E. Trauth, Dept. of Biological Sciences, ASU, State University, AR 72467.

A COMPARISON OF EIGHT AGING TECHNIQUES OF WHITE-TAILED DEER (Odocoileus virginianus) IN ARKANSAS.
Bruce Shackleford. Biology, UCA, Conway, AR 72032.

SURFACE TOPOGRAPHY OF THE TONGUE IN THE NINE-BANDED ARMADILLO.
Douglas Eldro (UALR), William R. Bowen (UALR), Gary A. Heidt (UALR), Robert Sikes (MSU), and Tina Green (IPC). Biological Sciences Dept., UALR, Little Rock, AR 72204; Dept. of Biology, MSU, Memphis, TN 38152.

UNUSUAL HUMMINGBIRDS IN ARKANSAS.

AQUATIC - ENVIRONMENTAL II
Session Chairperson: Bruce Shackelford
(Arkansas Department of Pollution Control and Ecology)

REPRODUCTION AND HABITAT SELECTION IN TWO SPECIES OF DARTERS (OSTEICHTHYES: PERCIDAE) IN THE UPPER SALINE RIVER, SALINE COUNTY, ARKANSAS.
John Rickett and Diana Garland, Biology Department, UALR, Little Rock, AR 72204.

http://scholarworks.uark.edu/jaas/vol42/iss1/1
THE EFFECTS OF BARITE MINING ON THE SOUTH FORK OF THE CADDIO RIVER.
George L. Harp and Paul L. Raines, Department of Biological Sciences, ASU, State University, AR 72467.

SPawning FREQUENCY AND FECUNDITY OF BLUE TILAPIA.
Thomas J. Aureli and Les Torrans. Arkansas Power and Light Co., 9005 Penrose Lane, Little Rock, AR 72205; and Dept. of Agriculture, UAPB, Pine Bluff, AR 71601.

COMPARATIVE FEEDING HABITS OF CREOLE (Etheostoma collettei) AND REDFIN (E. whipplei) DARTERS IN THE UPPER SALINE RIVER, SALINE COUNTY, ARKANSAS.
Diana Garland and John Rickett, Biology Department, UCA, Conway, AR 72032.

BIOMEDICAL - MICROBIOLOGY II
Session Chairperson: Dr. Scott Kirkconnell (Biology, ATU)

A NEW LOOK AT GRANULOPOIESIS IN MOUSE BONE MARROW.
Bonnie L. Wright and William C. Guest. Arkansas Children's Hospital, Little Rock, AR 72205; Dept. of Zoology, UA, Fayetteville, AR 72701.

SURVIVAL AND GROWTH OF Trichomonas vaginalis IN HUMAN SEMEN.
Lynn Green, Jerome Sherman, Terry Hostetler, and James Daly. Dept. of Chemistry, MSU, Memphis, TN 38152; Dept. of Anatomy, UAMS, Little Rock, AR 72204; and Dept. of Microbiology and Immunology, UAMS, Little Rock, AR 72204.

RADIOPROTECTION OF MICE BY MANGANESE(II)(3.5-DIISOPROPYSALICYLATE).
William M. Willingham (UAPB), LaWanda D. Jones (UAPB), Kyle B. Bond (UAMS), Ahmad Salar (UAMS), and John R. J. Sorenson (UAMS). Dept. of Chemistry, UAPB, Pine Bluff, AR 71601; Dept. of Biopharmaceutical Sciences, College of Pharmacy, UAMS, Little Rock, AR 72205.

ALTERATIONS IN TUMOR BINDING BY SPLEENOCYTES AND PERITONEAL EXUDATE CELLS FROM cis-DIAMINEDICHLOROPLATINUM(II) TREATED L1210 TUMOR-BEARING MICE.
Bruce M. Whitney Dwight Talburt, Dept. of Botany and Bacteriology, UA, Fayetteville, AR 72701.

SCANNING ELECTRON MICROSCOPIC DEMONSTRATION OF THE BACTERIAL GLYCOALXYS.
W. Bowen (UALR), M. Klev (UALR), B. Good (UALR), M. Bartelt (UAMS), R. Evans (UAMS), C. Nelson (UAMS), and B. Harrison (UAMS). UALR, Little Rock, AR 72204; UAMS, Little Rock, AR 72205.

CORRELATION BETWEEN ISOLATION PH AND LEVELS OF RESISTANCE IN FLUORIDE-RESISTANT MUTANTS OF Streptococcus mutans.

ANTIVIRAL MANGANESE(II) COMPLEX WITH SUPEROXIDE DISMUTASE-MIMETIC ACTIVITY.

TESTING A MODEL FOR ISOCHROMATID DEPLETION PRODUCTION RESULTING FROM UV IRRADIATION OF GI PHASE HAMSTER CELLS.

CHEMISTRY II
Session Chairperson: Dr. William Trigg (Chemistry, ATU)

HIGH TEMPERATURE CHEMISTRY OF ETHANOL-FIRED MAGNETOHYDRODYNAMICS. I. COMBUSTION STUDIES.
J. Edward Bennett, Michael Martin, and Colin Hester. Dept. of Chemistry, ASU, State University, AR 72467.

HIGH TEMPERATURE CHEMISTRY OF ETHANOL-FIRED MAGNETOHYDRODYNAMICS. II. EXPERIMENTAL SYSTEM FOR CHARACTERIZATION OF THERMAL IONIZATION.
J. Edward Bennett, Michael Martin, and Colin Hester. Dept. of Chemistry, ASU, State University, AR 72467.

THE MASS SPECTRA OF OXAZOLIDINES FORMED BY CONDENSATION OF EPHEDRINE AND PSEUDOEPHEDRINE.

RUTHENIUM MERCAPTAN COMPLEXES.
D. Minick (ASU), M. Dragana (ASU), F. Evans (NCTR), and A. W. Cordes (UA). Dept. of Chemistry, ASU, State University, AR 72467; National Center for Toxocological Research, Jefferson, AR 72079; and Dept. of Chemistry and Biochemistry, UA, Fayetteville, AR 72701.

RING-OPENING AND RING-FORMING POLYMERIZATIONS: POLYAMINES AND POLYAMIDES FROM Diallylamine and Ethyloxazoline.

THE OXIDATION OF ALCOHOLS WITH CHROMIUM TRIOXIDE IN ACETONITRILE.
Paul M. Nave and D. B. Holt, Dept. of Chemistry, ASU, State University, AR 72467.

MONITORING SURFACE WATER FOR ORGANOCHELORINE PESTICIDES AND PCBs FROM 121 SAMPLE SITES OF THE NORTHEAST ARKANSAS ENVIRONMENTAL QUALITY GRID.
William V. Wyatt and Paul D. Gwinup. Dept. of Chemistry, ASU, State University, AR 72467.

LICHENS AS AIR QUALITY MONITORS.
William V. Wyatt, Paul D. Gwinup, and Johnny W. Cude. Dept. of Chemistry, ASU, State University, AR 72467.

PHOTOCHEMISTRY OF CYCLOPENTADIENYL BRIDGED DINUCLEAR COMPLEXES.
E. F. Askew and B. Durham. Dept. of Chemistry and Biochemistry, UA, Fayetteville, AR 72701.

INVERTEBRATE ZOOLOGY
Session Chairperson: Dr. Raymond D. Cousar (Biology ATU)

TWO NEW SPECIES OF DIPLURA FROM THE OUACHITA MOUNTAINS OF ARKANSAS.
Robert T. Allen, Department of Entomology, UA, Fayetteville, AR 72701.
CORTICAL SINGLET MICROTUBULES AND MOTILITY OF THE AFLAGELLATE SPERMATOZOOON OF Hydrolymax.
W. Donald Newton, Department of Biological Sciences, ASU, State University, AR 72467.

ADDITIONS TO THE KNOWN ENDEMIC FLORA AND FAUNA OF ARKANSAS.
Robert T. Allen, Department of Entomology, UA, Fayetteville, AR 72701.

NOTES ON THE BIOLOGY OF Thyanta calceata (HEMIPTERA: PENTATOMIDAE) ON Tephrosia virginiana (LEGUMINOSAE), A NEW HOST PLANT.
Phoebe A. Harp and Harvey E. Barton, Department of Biological Sciences, ASU, State University, AR 72467.

PHYSICS - MATHEMATICS
Session Chairperson: Dr. Mostafa Hemmati, Physics, ATU

ON THE APPLICABILITY OF STOKE'S LAW.

MEASUREMENTS OF THE DRAG ON SPHERES FALLING THROUGH THE AIR.

ANALYSIS OF HIGH TEMPERATURE SERIES IN CRITICAL PHENOMENA USING FIRST ORDER ORDINARY DIFFERENTIAL APPROXIMANTS.
M. J. George, Dept. of Computer Science, ASU, State University, AR 72467.

X-RAY WOOD DENSITOMETER.
Hudson B. Eldridge, Bruce A. Yee, and Harold L. Pray. Physics Dept., UCA, Conway, AR 72032.

EQUATIONS OF VARIATION FOR ORDINARY DIFFERENTIAL EQUATIONS ON MANIFOLDS.
John B. Bennett. Dept. of Computer Science, Mathematics, and Physics, ASU, State University, AR 72467.

THERMAL DIFFUSIVITY OF YITTRIUM ALUMINUM GARNET AND YITTRIUM ALUMINATE BETWEEN 20 AND 200 DEGREES CELSIUS.
John Beasley and Pradip Bandopadhyay. Department of Physics, Hendrix College, Conway, AR 72032.

X-RAY SPECTROMETER APERATURE MEASUREMENT.

AN EXPERIMENTAL INVESTIGATION OF EXCITED STATE ABSORPTION OF DIVALENT EUROPINIUM IN ALKALI HALIDES.
Stephen Fenno and Pradip Bandopadhyay. Department of Physics, Hendrix College, Conway, AR 72032.

X-RAY FLUORESCENCE ANALYSIS OF TREATED WOOD.

IONIZING WAVES MOVING INTO A PREIONIZED MEDIUM:
SOLUTIONS OF THE ELECTRON FLUID DYNAMIC EQUATIONS FOR QUASI-NEUTRAL REGION (CLASS II WAVES).
Mostafa Hemmati. Physical Sciences Dept., ATU, Russellville, AR 72801.

SCIENCE EDUCATION II
Session Chairperson: Dr. Robbin Anderson (Chemistry, UA)

STATUS REPORT AND PROJECTIONS: NEW ARKANSAS STANDARDS SEEN IN EFFECT.
R. C. Anderson, Dept. of Chemistry and Biochemistry, UA, Fayetteville, AR 72701.

LAB SAFETY - BUSINESS AS USUAL?
Michael W. Rapp, Dept. of Chemistry, UCA, Conway, AR 72032.

AN ACADEMIC SCIENTIST'S ROLE IN ECONOMIC DEVELOPMENT: ONE PERSON'S VIEW.
Collis Geren. Dept. of Chemistry and Biochemistry, and the Arkansas Biotechnology Center, UA, Fayetteville, AR 72701.

NSF UNDERGRADUATE SUPPORT PROGRAMS.
Karl David Straub, John L. McLeod VA Hospital, Little Rock, AR 72204; and Richard Anderson, Physics Dept., UA, Fayetteville, AR 72701.

A SIMPLE EXERCISE TO ILLUSTRATE UNCERTAINTY OF MEASUREMENT AND SIGNIFICANT FIGURES.
Syed M. Alijaz, Chemistry Dept., UAPB, Pine Bluff, AR 71601.

COMPUTER AIDED INSTRUCTION AND STUDENT REMEDICATION: A PROPOSAL FOR ARKANSAS.
J. Edward Bennett and Tom Barber. Dept. of Chemistry, ASU, State University, AR 72467.

THE VETERANS ADMINISTRATION ENGINEERING TRAINING CENTER.
J. O. Wear. Eng. Trn. Ctr. (10A4A), VA Medical Center, North Little Rock Division, North Little Rock, AR 72114.

VERTEBRATE ZOOLOGY II
Session Chairperson: Dr. Tom Nelson (Fisheries and Wildlife Management, ATU)

IDENTIFYING FACTORS AFFECTING ANNUAL DEER HARVEST IN ARKANSAS.
R. A. Kluender (UAM), T. B. Wigley (UAM), and M. E. Cartwright (AG&FC). Dept. of Forest Resources, Arkansas Agric. Exp. Sta., UAM, Monticello, AR 71655; Arkansas Game and Fish Commission, Rt. 1, Box 56, Calico Rock, AR 72519.

COMMENTS ON ESTIMATING RATE OF INCREASE FROM AGE FREQUENCY DATA.
Renn Tumlison and V. R. McDaniel. Dept. of Zoology, OSU, Stillwater, OK 74078; and Dept. of Biological Sciences, ASU, State University, AR 72467.

FOREST HABITAT USE BY WHITE-TAILED DEER IN THE ARKANSAS COASTAL PLAIN.

FEEDING BEHAVIOR, FOOD, SEX RATIOS AND MEASUREMENTS OF THREE SPECIES OF WATER SNAKES COLLECTED IN NORTHEASTERN ARKANSAS.
Walter Meshaka, William Byrd, and Earl Hanebrink. Dept. of Biological Sciences, ASU, State University, AR 72467.

MANDIBULAR DENTITION IN SIX SPECIES OF SALAMANDERS, GENUS Plethodon (CAUDATA: PLETHODONTIDAE), FROM ARKANSAS USING SCANNING ELECTRON MICROSCOPY.
Richard A. Atwill and Stanley E. Trauth. Dept. of Biological Sciences, ASU, State University, AR 72467.
TOE TIP SURFACE MORPHOLOGY IN SIX SALAMANDER SPECIES, GENUS *Ambystoma* (CAUDATA: AMBYSTOMATIDAE), FROM ARKANSAS USING SCANNING ELECTRON MICROSCOPY.
Stanley E. Trauth and J. D. Wilhide. Dept. of Biological Sciences, ASU, State University, AR 72467.

SEX RATIOS IN BOBCAT POPULATIONS.
Renn Tumlison and V. R. McDaniels. Dept. of Zoology, OSU, Stillwater, OK 74078; and Dept. of Biological Sciences, ASU, State University, AR 72467.

A PRELIMINARY INVESTIGATION OF HERPTILES INHABITING THE STATE PARKS OF ARKANSAS.
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SURVEY OF BATS IN THE OUACHITA MOUNTAINS OF ARKANSAS.
David A. Saugey (USFS), Gary A. Heidt (UALR), and Darrell R. Heath (UALR). U.S. Forest Service, Hot Springs, AR 71902; Dept. of Biology, UALR, Little Rock, AR 72204.
IN MEMORIAM: LOWELL F. BAILEY, 1911-1988

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Dr. Lowell F. Bailey passed away on December 5, 1988. He was a long-time member of the Arkansas Academy of Science serving as its President in 1965. He was born June 15, 1911 at Holton, Kansas. He was graduated from Southern Illinois State Teachers College in 1932 and received his Ph.D. from the University of Michigan in 1939. He then held faculty positions at the Universities of Kentucky and Tennessee before coming to the University of Arkansas where he was a Professor of Botany and Bacteriology from 1951 until he retired in 1978. He was Chairman of the department from 1963 until 1975. He was a plant physiologist with research interests in plant chemistry and growth regulators. He directed research for graduate students and taught general botany and plant physiology. He was an inspiring and innovative teacher having installed the audio-tutorial laboratory for general botany courses at the University of Arkansas.

Lowell had the greatest concern for science education in the secondary schools as well. After Sputnik was launched in 1957, he was one of the first to apply for and obtain NSF grants for Summer Science Institutes for high school teachers. Science education in Arkansas was helped tremendously by these programs. He was also a major force in the establishment and organization of science fairs for high school students and gave encouragement to the Arkansas Science Talent Search programs for high school seniors. He had a major role in keeping the Academy alive and active during slack years in the late fifties and sixties. He was greatly concerned about environmental problems at this time and participated in national and state forums in that regard. He also encouraged pursuit of ecological studies within the department and served on the committee that developed the curriculum for the environmental science degree program at the University of Arkansas, Fayetteville.

During the many years of his tenure he personally took care of the botany greenhouse as if it was his bailiwick. He put in long hours and did not shirk from performing even menial tasks to keep it in opera-tions when money was short and trained help unavailable. When the department was moved from Old Main to the present Science Engineering Building, he was the person most involved in the planning and construction of the new greenhouse. The result of his effort is a very fine facility which serves both teaching and research activities today. It is a fitting monument to his care and commitment of time and effort which went into it.

Lowell’s life was one of total dedication having its greatest impact while he was chairman of the department. He once stated that as chairman he considered it his responsibility to provide his faculty with the most time and best facilities possible for them to pursue their teaching duties and research. So he shouldered all of the usual departmental administrative duties he could to spare his colleagues. Even so he was always ready to listen to people and help them when he could. His colleagues who knew and served with him were aware of how hard he worked, but he was such a quiet and unassuming man that many did not know the extent of his dedication. His wise counsel and commit-ment sustained the department and university exceedingly well during the time of rapid growth for the university in the late sixties and early seventies.

In addition to his service as department chairman, he was chairman or member of numerous university committees. He was the Universi-ty’s council representative to the Oak Ridge Institute of Nuclear Sciences, a fellow of the American Association for the Advancement of Science, and a member of Sigma Xi and other professional organizations.

He is survived by his wife Alice of Fayetteville, a son Jack of Madison, Wisconsin, and a brother Ralph Bailey of Haddonfield, New Jersey.
IN MEMORIAM: MAXINE CLARK, 1905-1988

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Maxine Clark, longtime student of plants in Oklahoma and Arkansas, died at Fayetteville, Washington County, Arkansas, on 11 January 1988 at the age of 82. In her last years she was debilitated by Alzheimer’s disease, the effects of that condition first appearing in 1978. The ravages of Alzheimer’s advanced rapidly to the point that the loss of memory forced her to abandon almost all things botanical. Thus, the botanical community lost in premature fashion one of its most enthusiastic practitioners.

The daughter of Alexander Thomas and Iva Jane (Bradford) McMurtrey, she was born in Salem, Missouri, on 17 October 1905. She married Joseph Marsh Clark, at Steelville, Missouri, on 3 November 1929. She is survived by her husband and two sons, Joseph Henry Clark, of Dallas, Texas, and Thomas McMurtrey Clark, of Lafayette, Louisiana, as well as five grandchildren and six great-grandchildren. Burial was at Fairview Memorial Gardens, Fayetteville.

The Clark family lived for many years at Tulsa, Oklahoma, where Joe worked as a professional geologist. Maxine studied botany under Dr. Ralph Kelting at University of Tulsa, where she received her M.A. degree in Botany in 1959. Her thesis, entitled A Study of the Flowering Plants of Tulsa County, Oklahoma Exclusive of the Grasses, Sedges, and Rushes, was a fine floristic study and gave her a depth of experience and appreciation for all plant groups. The collections from that study are deposited at the herbarium of University of Tulsa. Maxine was a long-time friend there of Dr. Harriet G. Barclay and credited Dr. Barclay for stimulating her interest in field botany.

Following retirement Joe and Maxine moved to Fayetteville, Arkansas, and they quickly became actively involved in many aspects of Arkansas’ natural history. His interests in geology and hers in botany took them to the outdoors, always working together as a team. They were charter members of the Ozark Society and served as editors of the award-winning Ozark Society Bulletin during 1967-1981. During their tenure with the Bulletin they helped make all aspects of natural history come alive to many people. Active canoeists and hikers, they made many treks into the Arkansas backcountry, always with a camera and a plant press. Maxine’s feature column, called Botanical Notes, appeared in the Ozark Society Bulletin during the period of 1967-1981. Her column was of high quality and gave insight into the depth of her botanical understanding.

Her many years in Oklahoma gave her an appreciation of prairie and prairie plants. She was one of the first to recognize the few Lindley Prairie remnants in Benton County, Arkansas, and studied them for years. Her observations on two of the small prairie remnants were recorded in a 1977 paper (Clark. M. B. 1977. Remnant prairie plots of Benton County, Arkansas. Proc. Ark. Acad. Sci. 31:112-114.)

She was fascinated by ferns and one of her significant Arkansas finds was a Boston Mountain station for the Filmy Fern (Clark, M. B. 1962. Trichomanes boschianum in Madison County, Arkansas. Amer. Fern J. 52:85-86). Her collection served as a stimulus in the successful search for other stations in northwest Arkansas.

Maxine loved plants and she loved to make botanical specimens. She accumulated a sizeable collection of specimens and regularly worked with them. The specimens were stored at her home for many years until finally they were transferred to the herbarium at Arkansas Tech. Many of them were badly damaged by insect and water damage, but many more were salvaged. The collections are probably strongest in the prairie species, but she also collected many specimens from forest communities in the Ozarks and Ouachitas.

She was a member of the Arkansas Academy of Science, a charter member of the Arkansas Native Plant Society, and an honorary member of the Ft. Smith Geological Society. In addition, she was an active member of the Fayetteville Garden Club.

Maxine was a real botanist, familiar with botanical literature and the plants themselves. Those of us in the Arkansas botanical community who knew her well will miss her. Those who came along too late to know her will never know the curious mix of gentility and grit that she was. One of her closest friends has confided that she always saw many parallels between Maxine and the late artist Georgia O’Keeffe. Maxine, too, had the eye of an artist and always appreciated the beauties of all of nature. A visit to her home was something like being in a combination of gallery and natural history museum. But, whereas the world of O’Keeffe defied convention, Maxine always worked within the realm of that which was proper. In the words of a popular song — “she was a lady.” And what a remarkable lady she was.
Delzie Demaree, American botanist and noted plant collector, was born at Benham, Indiana, on 15 September 1889. A longtime Arkansas resident, he had lived at Avery, Texas, since 1981. He died in Texas on 2 July 1987 at the age of 97. This paper presents a glimpse of Demaree as seen from the eyes of a friend and field companion. Delzie Demaree was a friend who was bigger than life to me. Some of this assessment of his life and work may appear to be less than objective, but Demaree was a person who touched the emotions of anyone who knew him. Often I’ve heard him say “if I had to work to make a living it would be as a forester,” but field botany was the discipline that kept him busy for many years. One had the feeling in talking with him that teaching was a vehicle allowing for field work, but wasn’t of great significance in itself. Learning for him was found in the field.

An important era in the history of Arkansas botany passed with Delzie Demaree. His death, combined with that of Dwight Moore just slightly more than two years earlier, leaves us with no one else from that generation. Their lives were intertwined, both professionally and personally, for many years, and it is difficult to discuss one without the other. They were very different personalities and yet their capabilities complimented each other well.

Demaree’s life was remarkable in several respects, but particularly in that it spanned so many changes in science and education. He was perhaps a man who came too late. Had he worked two hundred years earlier he would have been recorded as one of the world’s great botanical explorers. Of that I am certain. No explorer of the classical age of botany ever worked harder, longer, or more diligently in the field than he. Many summer days in the field with him in Arkansas convinced me of that.

A full account of Demaree’s biographical data has been given elsewhere (Sida 9:269-286. 1982.). Academy members should know, though, that he taught at several Arkansas institutions. His first job was at Hendrix college, 1922-26; he loved to say he was the only person in the state teaching evolution legally at that time and in a church school at that. Later he taught at the University of Arkansas, Fayetteville, 1926-30; Arkansas A. and M., Monticello, 1936-46; and Arkansas State, Jonesboro, 1946-53. Following retirement from Arkansas State University he moved to Hot Springs, where he lived until 1981. The last few years of his life were spent in east Texas, near the home of his daughter, Martha Davis.

During his lifetime Demaree devoted unceasing effort toward collecting, seemingly in search of at least one of everything he could find. That meant plants, but it also meant petrified wood, shark’s teeth and other fossils, novaculite, and snakes. He started collecting plants in 1922, when at Hendrix, and by his death he had amassed a total of 75,000 collection numbers in his ledgers. He collected throughout the United States, but more extensively in Arkansas than anywhere else. He is said to have collected more Arkansas specimens than any other collector. Those numbers were important to him, and the field of botany owes him a debt of gratitude for them. Countless graduate students across the country were assisted by him in their dissertation and thesis work. Who can say how many thousands of specimens, both living and preserved, were mailed to students and others involved in research?

One of Demaree’s peculiarities relating to plant specimen labels should be mentioned. He had an old multi-volume set of books that gave post offices and elevation readings for each. When he distributed specimens his label data listed the closest post office (within the county) to the collection site. Unfortunately, the label usually gives only the post office without specific mileage or directions to the site. That is a source of consternation to those trying to re-locate rare plant localities, but one must remember that Demaree came from an era when exact localities seldom were noted on labels. In early years of collecting he took elevation readings from his books but in later years always carried an altimeter with him and was forever checking altitudes to see if it agreed with the books. Labels included an elevation reading wherever possible.

I will remember meeting Demaree for the first time. When I was a botany graduate student at the University of North Carolina, Chapel Hill, he visited there each spring. He knew Harry Ahles, Herbarium Curator, and regularly sent him plants for identification. It was a departmental joke that the arrival of Demaree’s huge boxes would cause Ahles to laughingly say, “Here comes another bale of hay from Demaree.”

Demaree and I met at the herbarium in the spring of 1966 and spent much of that day together. Later that spring I accepted a position at Arkansas Tech, but thought little more about my new Arkansas acquaintance, Demaree. In September, with the task of settling in at Russellville far from complete, plant collecting was not a high priority on my list. But that first week on the job I received a postcard from Demaree, saying simply: “Meet me at Benton bus station, Saturday morning, 9:00. Bring lots of press material and I’ll show you some plants.” That was the first of many trips to the field with Demaree.

On his second trip to Russellville Demaree dug deep into his boxes and came up with what looked like something very special. Wrapped in numerous layers of newspaper and held together with layers of red plastic tape was a copy of his famous little publication: Taxodium, Vol. 1, No. 1. I was unaware of this 1943 checklist of Arkansas plant species, so he told me the story of its production and distribution. He had initiated the journal, named it after his favorite tree, had it privately printed, and tightly controlled its limited distribution. No one in Arkansas, he said, had personal copies but him and me! And it was to stay a secret! Later he showed me his cache of copies in a dresser drawer at his home. How many other people had copies I don’t know.

The 1943 checklist apparently was many years in the making. In a letter to Carleton Bail, dated 15 July 1936, Demaree wrote: “I am working on a report of a checklist of Arkansas plants combining the Branner and Coville list, the Palmer and Buchholz supplement of 1926 to the above, plus my collections since 1926 and any others that I can find.” (Letter in manuscript collections at Hunt Institute, Pittsburgh.)

The story of a supposed feud between Demaree and Dwight Moore has been told for years. Demaree himself said things to support the feeling they were less than close friends. Ultimately I came to know both well but basically heard only Demaree’s side of the story. On a single occasion Moore made passing reference to Demaree’s displeasure with him due to a misunderstanding over a teaching position. I knew what he referred to, because Demaree had told me the story many times. In his later years, Demaree had come to the conclusion that Moore was guilty of two things: (1) causing Demaree to lose his Fayetteville position and end up with only a temporary job in Oklahoma, and (2) taking Demaree’s discoveries and publishing them under his own name. As evidence, Demaree said he published a woody checklist in 1933, only to have Dr. Moore publish another one in the 1941 Academy Proceedings. At that point Demaree would say the reason he published his Taxodium checklist privately and without state distribution was to keep Moore from seeing it and publishing it as his own.

One of my fond memories relates to Demaree’s 85th birthday party. On 14 September 1974 a group of his friends held a birthday party at Hot Springs, a beautiful affair with many in attendance. After blowing out the candles on the cake he went to the microphone and presented each guest with a small remembrance. Under the head table Demaree sat, listening to people introduce themselves. He was unaware of the proceedings.

On completing his birthday Demaree’s story would take on a new twist. He gave his copy graciously and in the dim light of the setting had little chance of reading the title page to see how old it was. I heard him compliment Demaree on “finally getting this job done” and Demaree’s reply was, “Hell, Doc, I did that back in 1943.”

So—often I’ve wondered about Demaree’s story that Moore had wrestled his Fayetteville teaching position away from him. Demaree had gone to Stanford to seek a doctorate and was to return to Fayetteville upon completion of the degree. On his return he found the job had been given to someone else, but Moore had arranged for an Oklahoma job. On his arrival at Oklahoma, however, he found the job was only temporary.

Recently, while assisting Mrs. Moore in sorting Dr. Moore’s personal papers, I was looking through a box of postcards and came across this one. The handwriting was in pencil, and consisted only of a postmark from New York dated 14 December 1943.

“Delzie, Your postcard was received and your taxodium list is collected with great interest. Appreciate your efforts in it. I hope to have the Arkansas Academy of Science, Vol. 42 [1988], Art. 1

http://scholarworks.uark.edu/jaas/vol42/iss1/1

18
Gary E. Tucker

papers I had the chance to examine and copy correspondence from the period involved (all correspondence now part of the Dwight Moore collection, Special Collections, University of Arkansas Library). Moore's correspondence to and from Demaree was extensive and indicates that Demaree's whereabouts were unknown to Moore for many months following completion of his doctoral program. Moreover, the correspondence clearly indicated that Demaree did not personally notify Moore of completion of the doctoral requirements. Moore's contention that another person finally was appointed to Demaree's position when he couldn't be found is confirmed by the correspondence.

Demaree completed his doctoral work at Stanford in 1932, but in a letter dated 7 March 1934 Moore wrote: "You never let us know about the completion of your doctor's work, but I have heard of it in an indirect way and would like to congratulate you on it." Demaree replied on 11 March 1934: "Thanks for the degree congratulations. I never tell anyone unless I have to. So few are really interested in education."

The Oklahoma position was discussed in a letter from Demaree to Moore on 8 April 1936. Demaree wrote: "When I received your letter I wired them that I would accept the proposition on Friday morning. Saturday they wired me that due to changes the position would be for only three months. On the following Wednesday they wired me to decline or accept by six o'clock. I accepted. I arrived here on Sunday and Dr. Cross was making mention of two telegrams and finally asked him what he meant about two. Then he asked me if I had not received two. Well, I did not get the first one as it did not leave the Norman office. About this time the operator was fired and in Texas. Since the U. does not have a copy of the telegram the W. U. (presumably Western Union) is free. Dr. Cross is trying to fix it for me to stay but I think the chances are slim." There was absolutely no animosity expressed in the letter.

Correspondence between Demaree and Moore continued regularly over a period of many years and generally was lengthy, detailed, and warm and cordial in nature. In a letter of 19 November 1941, Demaree wrote to Moore: "My list of ligneous plants is no good because it was published before I had it ready... Even my name was spelled wrong... I never did distribute it."

Whatever the nature of any difference between the two men, it would appear that time may have altered if not exaggerated the original circumstances. That, to me, changes nothing, but only adds to the mystique of the man Demaree.

What a pity so few of today's graduate students get the chance to work with people of Demaree's genre. It is sad, but true, that too many botanists have been reared in a new age and with a new set of values. It hurts to see papers saying such things as, "In the history of Arkansas botany, the ultimate unworkable and untenable floristic list for the state is that by Demaree (1943), which includes every imaginable type of error in compilation and judgment." (Phytologia 64:82. 1987). Such a comment serves as proof that some of our botanists are sadly lacking in courtesy and tact if not ethics. Moreover, such comments show little appreciation or depth of understanding of the nature of pioneering work. Any person who collects over 75,000 numbers of plant specimens in a lifetime (without owning or driving a car) has to be doing something right. Moreover, those 75,000 numbers were accumulated without an expense account or grant money. Anyone failing to recognize the value of the 1943 checklist reveals a lack of understanding of the basic workings of science.

The author of a 1973 paper (Castanea 38:79, 1973.) included a statement critical of Demaree's failure to distribute his 1943 checklist to libraries and the Arkansas scientific community. The article stated, "... this was an unfortunate choice... since it delayed the work on a Manual or Flora for the state of Arkansas..." That comment hurt Demaree deeply and he considered it an indictment of his character. And yet, probably there is a good deal of accuracy in the statement. It is interesting to contrast that author's assessment ("delayed work on a state Flora") against the more recent comments ("ultimate unworkable and untenable floristic list for the state").

Any pioneering work will have its deficiencies. Hindsight always is better than foresight, though, and it always is easier to have a strawman to knock down than to erect the strawman in the first place. Somewhere I recall hearing the phrase "walking on the shoulders of giants." It seems appropriate in this discussion.

In conclusion, Arkansas botany is richer for having experienced the life and work of Delzie Demaree. The tributes paid to him in the special section of Sida (Sida 9:269-289, 1982.) are ample indication that professionals across the country recognized his contributions. To his few detractors I would hope that age and maturity may mend the imperfections of intellect and ego. This state can be proud of its adopted son, Delzie Demaree. When and if a state flora is produced for Arkansas the totality of Demaree's work of a lifetime will stand for what it was — a monumental pioneering effort of permanent value.

ACKNOWLEDGEMENTS

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ADDITIONS TO THE KNOWN ENDEMIC FLORA AND FAUNA OF ARKANSAS

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ABSTRACT

Robison and Smith's (1982) list of endemic species of Arkansas rendered a valuable service to the community of biologists interested in the endemic biota of the state. These authors listed seven species of plants and forty species of animals endemic to Arkansas. This paper, under the aegis of the Ozark/Ouachita Mountain region of Missouri, Arkansas, and Oklahoma, adds to the knowledge of the endemic biota of the Ozark/Ouachita Mountain region of Missouri, Arkansas, and Oklahoma. During the course of compiling a list of Ozark/Ouachita endemic species several references were found that listed Arkansas endemic taxa inadvertently overlooked by Robison and Smith. Most notable among these references was Chamberlin and Hoffman (1958), Checklist of the Millipedes of North America. This paper chronicles the work of N. B. Causey and R. V. Chamberlin who describe thirty-two species of endemic Arkansas Millipedes. These records as well as a few additional records for other animal and plant taxa are presented in this paper.

INTRODUCTION

Various workers have discussed the taxonomic and geographic relationships between the biota of Arkansas and possible relatives in other areas of eastern North America (Tucker, 1976; Williams, 1954; Heighton, 1962; Ross, 1956; Ross and Ricker, 1971; Allen and Carlton, 1988). These papers and others leave no doubt that the Arkansas biota does have distinct affinities with the biota of eastern North America, especially at the species level. If one considers higher and more inclusive taxa such as genera, tribes, and/or families, taxonomic and geographic relationships with western North America also become evident. For example, the salamander genus Plethodon has a distinct endemic western element which is closely related to the eastern Plethodon species (Heighton, 1972). The ground beetle tribe Anilinini in which the genus Anilinus occurs in eastern North America has sister genera in west Texas and California. The lace bug genus Acotiopa has both eastern and western endemic sister groups including an Arkansas species known only from Logan County. This paper also notes one example in the millipedes, Cibularia profuga, whose nearest relative occurs in the southwest.

If we consider the origin and evolution of the biota of North America as a whole, the place of the Arkansas biota, especially the endemic biota of the Interior Highlands of Arkansas and Missouri, becomes a critical and important element. We might pose the question, "In America is there a western biota, a mid-continent (Interior Highlands) biota and an eastern biota whose various elements will show a repetitive sister group relationship or relationships?" When we consider the possibility of searching for an answer to the question just posed a knowledge of the endemic biota of Arkansas becomes crucial. And the answer to the question has far greater implications than just listing species that occur within the boundaries of the state. As we study the endemic biota of Arkansas we would be well advised to consider seriously not only the eastern affinities the taxa might exhibit, but also the possibility that western North America has played some role in the evolution of this rich biota.

ANNOTATED LIST

I. VASCULAR PLANTS.

Order Papaverales
Family Cruciferae — Mustard Family

1. Cardamine angustata O. E. Schulz var. ouachitana E. B. Smith, 1982:379. Type: University of Arkansas Herbarium. Type locality: Arkansas, Polk Co.: 12.1 miles south of the junction of highways 375 and 8 near Mena; 19 March 1982. Collector, E. B. Smith. Distribution: AR: Howard, Montgomery, and Polk counties. Remarks: Smith presents a discussion of this variety comparing it with the typical C. angustata angustata. He notes that the populations of nominate species and the new variety are disjunct by some "400 air Km" from populations in northeastern Mississippi and central Tennessee. There are five eastern species in the subgenus Dentaria to which Smith assigns this variety.

Order Rubiales
Family Rubiaceae — Madder Family


II. ANIMALS

Phylum Arthropoda
Class Myriapoda — Millipedes
Order Polydesmida
Family Desmonidae


Family Eurydesmidae

2. Cibularia profuga Causey, 1955:29. Type: American Museum of Natural History. Type locality: Arkansas, Montgomery Co., Mt. Ida, 5 miles south of the Ouachita River bridge; 14 April, 1954. Distribution: Known only from the type locality. Remarks: The type specimen, three males, three females, one larva, were collected under rocks. The area from which this species was collected is a mixture of pine and hardwood. There is one additional species in the genus, C. tuobita (Chamberlin), from Otero and Lincoln counties in central New Mexico.

3. Mimuloria davidcauseyi (Causey), 1950:194. Type: Philadelphia Academy of Sciences. Type locality: Arkansas, Newton Co., Jasper, about 3 miles northwest. Distribution: Known only from the type locality. Remarks: This species was originally placed in the genus Nannaria. Causey states that the "twice recently molted males and two larvae were collected by Dr. David Causey on 25 August 1950 from an oak-hickory woodland on an east hillside." There are five species in this genus, three from the Ozark Mountains and one each from Ohio and Indiana.

18 Proceedings Arkansas Academy of Science, Vol. 42, 1988
4. *Mimuloria depalmae* (Causey), 1950:1. Type: Philadelphia Academy of Sciences. Type locality: Arkansas, Carroll County, 2 mi. S. of Lake Leatherwood. Lake Leatherwood is east of Eureka Springs on Hwy. 62. Distribution: Known only from the type locality. Remarks: This species was originally placed in the genus *Castanaria*. Also see *M. davidcauseyi*.

5. *Pleurolopha mirabilis* (Causey), 1951:85. Type: Philadelphia Academy of Sciences. Type locality: Arkansas, Clay County, 12 mi. NE of Piggott, on highway 62. Distribution: Known only from the type locality. Remarks: Causey notes that the habitat of this species was “rather dry litter on a north oak-hickory covered hillside.” This species was originally placed in the genus *Zonaria*. Chamberlin and Hoffman note that there are twelve species in the genus and “most of which will probably be shown to be only geographic races of *P. flavipes*.” All of the species are eastern in distribution.

Family Euryuridae

The family is divided into two subfamilies. The Aphelidesminae is predominately Neotropical with one species known from Kerr county, Texas. The Euryurinae are known only from eastern North America.

6. *Auturus florus* Causey, 1950:37. Type: Philadelphia Academy of Sciences. Type locality: Arkansas, Newton County, Compton, Hemmed-in Hollow. Distribution: Known only from the type locality. Remarks: The type locality is now within the Buffalo National River Park. A special collecting permit is required. There are ten species in this eastern genus. One species *A. minuta* Chamberlin is endemic to the Christian and Jefferson counties in Missouri.

Family Eurymeresmidae

7. *Eurymerodesmus angularis* Causey, 1951:69. Type: Philadelphia Academy of Sciences. Type locality: Arkansas, Prairie County. Distribution: Known only from the type locality. Remarks: There are twenty-one species in the genus. All of the species are found in eastern North America.

8. *Eurymerodesmus bentonius* Causey, 1950:268. Type: Philadelphia Academy of Sciences. Type locality: Arkansas, Benton County, Monte Ne. Distribution: Known only from the type locality. Remarks: Much of the area around the Monte Ne community has been flooded by the impoundment of Beaver Lake Reservoir.


Order Chordeumida
Family Cleidogonidae


21. *Ofcookogona alia* Causey, 1951:121. Type: Philadelphia Academy of Sciences. Type locality: Arkansas, Union County, Junction City. Distribution: Known only from the type locality. Remarks: There are two species in the genus, both described from Arkansas by Causey (1951). *O. alia* was collected from a pine-hardwood forest on 25 December 1950 in Union County near Junction City.


Additions to the Known Endemic Flora and Fauna of Arkansas

Distribution: AR: Carroll and Washington Counties. Remarks: The type locality, Blue Spring, is now a commercial tourist attraction. It is located west of Eureka Springs on Highway 62.

Family Conotylidae

26. *Trigenotyla parca* Causey, 1951:118. Type: Philadelphia Academy of Sciences. Type locality: Arkansas, Carroll County, Blue Spring. Distribution: AR: Carroll and Washington counties. Remarks: This is a monotypic genus described by Causey (1951) and known only from northwest Arkansas. Blue Spring is now a commercial tourist attraction west of Eureka Springs on Highway 62.

27. *Craspedosoma flavidum* Bollman, 1888:2. Type: United States National Museum. Type locality: Arkansas, Clark County, Okolona. Distribution: Known only from the type locality. Remarks: The type species has apparently been lost. It should be noted that other species described in this genus by Bollman have either been synonymized or transferred to another genus, *Branneria*.

Order Julida
Family Parafulculidae


29. *Oktulus beveli* Causey, 1953:152. Type: American Museum of Natural History. Type locality: Arkansas, Union County, Junction City. Distribution: Known only from the type locality. Remarks: This genus was described by Causey for two species, *O. beveli* from Arkansas, and *O. carpenieri* Causey from Latimer County in Oklahoma.

30. *Oriulus grayi* Causey, 1950:50. Type: Philadelphia Academy of Sciences. Type locality: Arkansas, Prairie County, DeValls Bluff. Distribution: Known only from the type locality. Remarks: This genus contains eight additional species ranging throughout eastern North America with one species reaching as far west as Colorado and Utah.

Order Cambalida
Family Cambalidae

31. *Cambalida arkansana* Chamberlin, 1942:3. Type: R. V. Chamberlin Collection. Type locality: Arkansas, Randolph County, Pocahontas. Distribution: Known only from the type locality. Remarks: There are 10 additional species in the genus, all occurring in eastern North America.

Order Polyzonidae
Family Polyzonidae

32. *Polyzonium bikermani* Causey, 1951:138. Type: Philadelphia Academy of Sciences. Type locality: Arkansas, Washington County, Devil's Den State Park. Distribution: Known from the type locality only. Remarks: There are two additional, eastern North American species in the genus. The staphylinid beetle *Dorops divitalis* Sanderson was also described from Devil's Den State Park and is an Ozark endemic.

Class Symphyla — Symphylids
Order Symphyla
Family Neobisidae

33. *Microcreagris ozarkensis* Hoff, 1945:34. Type: Illinois Natural History Survey. Type locality: Arkansas, Washington County, Devil's

Den State Park; 3 October 1941. Distribution: AR; Washington county. Remarks: The allotype female was collected in Farmington which is also in Washington County. Both specimens were collected in "woody, leafy debris" (Hoff, 1958).

Family Chernetidae

34. *Pseudeosa occidentalis* Hoff & Bosterli, 1956:170. Type: Illinois Natural History Survey. Type locality: Arkansas, Washington County, Fincher Cave. Distribution: AR: Washington county. Remarks: The type series of this species was composed of a number of specimens from three caves in Washington County: Fincher Cave, Carrol Cave, and Stevenson's Cave. There is one additional species in the genus, *P. mirabilis* (Banks) known from Indian Cave Barren County, Kentucky.

Class Insecta
Order Diplura — Diplurans
Family Japygidae


Class Insecta
Order Coleoptera — Beetles
Family Scaphidiidae

36. *Scaphisoma arkansana* Casey, Type: United States National Museum. Type locality: Arkansas, Distribution: Known only from the type locality. Remarks: The original description only listed the state of Arkansas as the area from which this species came. Other records have not been reported in the literature.

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LITERATURE CITED


A NEW SPECIES OF OCCASJAPYX FROM THE INTERIOR HIGHLANDS
(INSECTA: DIPLURA: JAPYGIDAE)

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ABSTRACT

A new species of Japygidae, Occasjapyx carltoni is described from the Ozark Mountains of the Interior Highlands. This is the first record of the genus outside of California in North America. The genus is also known from China and Japan.

INTRODUCTION

The eyeless, soil dwelling insects of the family Japygidae in the order Diplura have received scant attention from North American entomologists. Only the California fauna has been studied in detail in a series of papers by Smith from 1959 through 1964. In one of these papers, Smith (1959) discussed the genus Occasjapyx. Smith characterized the genus as follows: (1) antennae 24 segmented, (2) first lamina of labial palp falciform, (3) tergite VII with postero-lateral angles directed posteriorly, (4) forcipules asymmetrical with two prominent teeth, (5) body without plumose body setae. These characters also serve to place the genus in the subfamily Japyginae.

Occasjapyx presently includes four California species, O. americanus (MacGillivary), O. californicus Silvestri, O. kohoi (Silvestri), and O. sierrensis Smith, five species from Japan, and four species from China (Reddell, 1983). This paper describes Occasjapyx carltoni, a new species from the Ozark Mountains of the Interior Highlands. The terminology used here follows that of Smith (1959) used for other species in the genus.

Occasjapyx carltoni new species


Etymology. This species is named in honor of my colleague and friend and the collector of the specimens, Mr. C. E. Carlton.

DESCRIPTION

HEAD. Dorsal surface with 24 M setae and numerous secondary setae, Fig. 1. Antennae: 24 segments; segment IV with two elongate hair-like sensillae Fig. 17; segment VI, length 0.27 mm., width 0.23 mm., longest data seta on segment VI 0.35 mm.; terminal segment, length 0.12 mm., width 0.06 mm., without placoid sensillae. Maxillae: first lamina of labial palp falciform, length 2-5 pectinate, Fig. 13; lateral margin of galea with 4 primary setae, 3 additional primary setae, in a row, near the midline, about 10 secondary setae present; thumb of galea bilobed, inner lobe rounded, with 6 sensory cones apically, 2 primary setae towards the base near the lateral margin, outer lobe broadly rounded, asetose, Fig. 14; labial palpi evenly narrowed from base to apex, length 0.20 mm., width at base 0.08 mm., Fig. 15; mandible with 4 teeth, Fig. 16.

THORAX. Pronotum: 5 + 5 M, Fig. 2. Meso and metanotum, prescutum: 1 + 1 M, Fig. 3. Scutum: 5 + 5 M, Fig. 4.

ABDOMINAL TEGITES. Figures 5-12. Segments I-VII with a median anterior pair of distinct setae, not decreasing in size posteriorly and a small pair of posterior median setae. I: 1 + 1 M; II: 3 + 3 M; III: 4 + 4 M; IV-VII: 5 + 5 M; VIII: 2 + 2 M; IX: 0; X: 2 + 2 M.

ABDOMINAL STERNITES. I: prescutum, 3 + 3 M; scutum, 15 + 15 M; II-VI: 16 + 1 + 16 M, 1 decreases in size posteriorly; VII: 18 + 18 M; VIII: 6 + 6 M; IX: 0; X: 13 + 13 M.

LEGS. Femur: with several primary and secondary setae. Tibia: setae more numerous in apical ¼. Tarsi: evenly narrowed base to apex; claws unequal, longest claw 2 Xs length short claw, empodium sclerotized, ¼ length or less of the longest claw; tarsal length, base to apex of longest claw 0.50 mm., width at base 0.11 mm.

SUBCOXAL ORGANS. Lateral: with 2-3 rows of glandular setae; sensory setae not evident; median subcoxal organ with about 13 short setae on each side of the organ; median area without disculi or setae.

FEMALE GENITALIA. Orifice elongate, transverse opening with narrow anterior and posterior flaps; anterior margin with about 20 setae, posterior margin with about 30 setae; papillae and/or sensory setae absent.

MALE GENITALIA. Gonopore: a narrow longitudinal slit; an anterior or posterior flap not evident; anterior margin with about 34 long setae in 2 (possibly 3) rows; posterior margin with about 37-40 small setae arranged in 2-3 rows, posterior to which are 14-16 longer setae arranged in 2 rows. Papillae: one each side, broadly rounded apically, with 40 + longer setae irregularly arranged, Fig. 18.

FORCEPS. Left cercus: 1 premedian and one post median tooth; predental tubercles 4, interdental tubercles 7, postdental tubercles 10. Right cercus: one premedian and one post median tooth; predental tubercles 5, interdental tubercles 3-4, postdental tubercles 14, Fig. 19.

DISCUSSION

The discovery of the genus Occasjapyx in the Interior Highlands presents an interesting distributional disjunction between the central and western United States. The majority of the Interior Highland endemic taxa have their closest affinities with taxa east of the Mississippi River. Smith (1960) also described a japygid, Eojapyx pedis Smith, from Missouri whose closest relatives in the subfamily Provalljapyginae are found only along the west coast of North America. However, since collections of Japygidae are rare and thus we know so little about the distribution of these insects, any definitive statement about this disjunct pattern would be premature.
ACKNOWLEDGEMENTS

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LITERATURE CITED


MANDIBULAR DENTITION IN SIX SPECIES OF SALAMANDERS, GENUS PLETHODON (CAUDATA: PLETHODONTIDAE), FROM ARKANSAS USING SCANNING ELECTRON MICROSCOPY

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ABSTRACT
The mandibular (dental) dentition of six species of Plethodon (P. caddoensis, P. dorsalis, P. fourchensis, P. glutinosus, P. ouachitae, and P. serratus) from Arkansas was studied using scanning electron microscopy. In all species, the mandibular teeth were bicuspid, and each tooth possessed a prominent labial cusp and a well-developed, inward-curving lingual cusp. All species showed similar tooth crown features, except P. caddoensis which exhibited a reduced tooth height and a reduced lingual cusp (only slightly larger than the labial cusp). We compared our data with other studies on premaxillary, maxillary, and palatal teeth in Plethodon and found overall similarities in tooth types. Tooth morphology does not appear to be an effective tool for taxonomic purposes in our Plethodon species because of the range of morphological variation in tooth structure.

INTRODUCTION
Amphibian teeth are divided into two parts, a basal pedestal and a distal crown or apex (Lawson, 1965; Moury et al., 1987). Teeth can be either monocuspid or bicuspid with the bicuspid condition being considered primitive and can be either monostichous, in a single row, or polystichous, in multiple rows (Wake, 1963; 1966; 1976). Within the family Plethodontidae, Cos (1974) found that the shape of the premaxillary and maxillary teeth of Plethodon ouachitae and P. glutinosus were bicuspid with a well-developed labial cusp. He also noted that these teeth in P. dorsalis were bicuspid and uniform in size with the labial cusp being more reduced in males (an indication of sexual dimorphism). Stewart (1958) stated that the maxillary and dentary teeth were similar in morphology in Eurycea bislineata with the exception of a gradual decrease in size and height posteriorly. Moury et al. (1987) studied the ultrastructural and histochemical features of monostichous teeth of the jawbones in P. cinereus and compared them to the palatal (polystichous) teeth. They found that the apices, or crowns, were similar in both kinds of teeth with the basal pedestals being heterogenous. Cos (1974) also found that the crowns were similar in external morphology with the Yo-nahlossee group, the Glutinosus group, and the Wehrlei group in Plethodon. He stated that in the Yonahlossee group, the species P. yonahlossee, P. ouachitae, and P. caddoensis had similar tooth morphologies as were P. glutinosus and P. jordani of the Glutinosus group. Highton and Larson (1979), using electrophoretic analysis of protein variation, revised the grouping of Plethodon and placed P. ouachitae, P. caddoensis, P. glutinosus, and P. fourchensis into the Glutinosus group, P. wehrlei and P. punctatus in the Wehrlei Group, P. serratus in the Cinereus group, and P. dorsalis in the Welleri group.

Although several studies have compared the morphology of premaxillary, maxillary, and vomerine (palatal) teeth in Plethodon, few have mentioned anything other than general morphology of the mandibular or dentary teeth (see Moury et al., 1987). No study using scanning electron microscopy (SEM) has been performed on the mandibular dentition of Plethodon species from Arkansas. Herein, we describe the mandibular teeth of six species of Plethodon (P. caddoensis, P. dorsalis, P. fourchensis, P. glutinosus, P. ouachitae, and P. serratus) from Arkansas using SEM. We also wished to determine interspecific differences and whether mandibular tooth morphology could be used as a reliable taxonomic tool. Lastly, we compare our observations with the current knowledge pertaining to premaxillary and maxillary teeth in Plethodon.

MATERIALS AND METHODS

The mandibular teeth of six species of Plethodon (N = 29) were examined (P. caddoensis—1 female, 3 males; P. dorsalis—1 female, 4 males; P. fourchensis—3 females, 2 males; P. glutinosus—2 females, 3 males; P. ouachitae—3 females, 2 males; P. serratus—3 females, 2 males). All specimens were collected in Montgomery, Polk, and Stone counties. Animals were sacrificed using a dilute chloretole solution, fixed within 24 h of collection in 10% formalin, and stored in 70% ethanol. Specimens were then measured and sexed. Lower jaws were excised and placed into vials of 70% ethanol. For SEM, mandibles were dehydrated in a graded series of ethanol and amyl acetate, dried in a critical point dryer, coated with gold/palladium, and viewed with a JEOL 100 CXII TEM/SCAN electron microscope at an accelerating voltage of 40 kV. Jaw teeth were counted after preparation for SEM using a dissecting microscope at 30X. All specimens and preparations are deposited in the Arkansas State University Museum of Zoology. When means are given, they are accompanied by ± two standard errors.

RESULTS

All mandibular teeth examined during this study were bicuspid and exhibited an elongate lingual cusp (except P. caddoensis) and a prominent, well-developed labial cusp. Teeth showed basic similarities among all species, and some degree of intraspecific variation was evident. In P. dorsalis and P. serratus, teeth showed a well-developed labial cusp with a long inward-curving lingual cusp (Fig. 1A & B). Each tooth also exhibited a posterior curvature as seen in dorsal view (Fig. 2A). In P. ouachitae and P. glutinosus, the teeth exhibited a prominent labial cusp with the lingual cusp being curved sharply inward (Fig. 2D-F). The labial cusp was almost vertical (anterior-to-posterior), or slightly curved posteriorly as observed in labial view (Fig. 1F).

Plethodon fourchensis exhibited a reduced labial cusp and a slightly incurving lingual cusp (Fig. 1D; 2B). The labial cusp was either vertical or slightly curved posteriorly.

In P. caddoensis, the teeth showed slightly-developed lingual and labial cusps with the lingual cusp being greatly reduced to such a degree that the lingual cusp was only slightly larger than the labial cusp (Fig. 1C; 2C). The teeth exhibited no inward curvature and were nearly vertical in anterior-to-posterior position. Although some variation was evident, both cusps showed a blunt to moderately tapering crest.
Figure 1. Scanning electron micrographs of mandibular teeth in species of *Plethodon* from Arkansas. All observations are labial views. A. *P. serratus*, 500X; line = 20 µm for A - C. B. *P. dorsalis*. C. *P. caddoensis*. D. *P. fourchensis*, 300X; line = 35 µm. E. *P. dorsalis*, 200X; line = 50 µm for E & F. F. *P. glutinosus*.

Figure 2. Scanning electron micrographs of mandibular teeth in species of *Plethodon* from Arkansas. All observations are dorsal views. A. *P. serratus*, 300X; line = 35 µm for A - C. B. *P. fourchensis*. C. *P. caddoensis*. D. *P. ouachitae*, 500X; line = 20 µm. E. *P. ouachitae*. F. *P. glutinosus*.

DISCUSSION

Our results confirm that mandibular tooth morphology in *Plethodon* is basically similar in structure to premaxillary and maxillary teeth as reported by Coss (1974) and Wake (1963, 1966). The teeth were bicuspid with the cusps showing varying degrees of development. The mandibular teeth of *P. glutinosus* and *P. ouachitae* possess the same morphological characteristics as their premaxillary and maxillary teeth. The only visible difference between these teeth was the width of the base of the tooth (widest in *P. ouachitae*). *Plethodon fourchensis* (not studied by Coss, 1974) was similar to *P. glutinosus* and *P. ouachitae*, except for the lingual cusp being sharply curved posteriorly. Although within the same phylogenetic grouping as *P. fourchensis*, *P. glutinosus*, and *P. ouachitae* (Duncan and Highton, 1979; Highton and Larson, 1979), *P. caddoensis* exhibited a distinctive mandibular tooth morphology with the lingual cusp being greatly reduced. This reduction in size of the lingual cusp would be a specialization for the Glutinosus group.

The tooth counts for the mandibular teeth in *P. glutinosus* and *P. ouachitae* were similar to the maxillary tooth numbers reported by Coss (1974). The mandibular tooth number in *P. dorsalis* and *P. serratus* were also very similar to the premaxillary/maxillary combined counts (Coss, 1974). Although *P. glutinosus* is considered a primitive species while *P. dorsalis* represents an advanced form (see Coss, 1974), the significance of mandibular tooth number and the correlation between body size and tooth number was not assessed during the present study.

Because of the range of variation, mandibular tooth morphology does not appear to be an effective taxonomic tool in *Plethodon* salamanders. The only species that possesses a distinctive cusp morphology is *P. caddoensis*. Otherwise, *Plethodon* species generally exhibit similar tooth structure among the various sets of teeth.

LITERATURE CITED


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EFFECT OF NITROGEN FERTILIZER ON MILLING QUALITY OF RICE (ORYZA SATIVA)

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ABSTRACT

The effect of nitrogen fertilizer on milling quality or milling yield of rice (Oryza sativa) was tested for two cultivars, 'Lemont' and 'Newbonnet'. This was an increase in the percentage of broken kernels and a decrease in head rice yield when no nitrogen fertilizer was applied as compared to applying all of the nitrogen at preflood or in split applications. The greater effect was on Lemont, a cultivar that requires a high amount of nitrogen fertilizer for maximum grain yields. Data showed that the percentage of head rice can be reduced by as much as 7 to 22 percent in Lemont and from 2 to 6 percent in Newbonnet when no nitrogen is applied as compared to applying all of the nitrogen at preflood or in split applications.

Also, these data show that the percentage of broken kernels can increase from 8 to 19 percent for Lemont and from 4 to 11 percent for Newbonnet when no nitrogen fertilizer is applied as compared to applying all of the nitrogen at preflood or in split applications.

INTRODUCTION

Milling quality of rice (Oryza sativa) is determined by the percentage of whole kernels (head rice), broken kernels, and total milled rice. In fact, the United States standards for rough rice and milled rice is based on the percentage of whole kernels and total milled rice (whole and broken kernels combined) that is produced in the milling of rough rice to a well milled degree (Morse et al., 1967). Rice producers received more than twice as much money for whole kernels as they did for broken kernels in 1988 (Anonymous, 1988). Therefore, it is imperative that producers understand the variables that influence milling quality of rice. The effects of moisture content of the grain at harvest on milling yield has been well documented. For example, Smith et al. (1938) showed in Arkansas and Texas in the 1930's that rice harvested between 23 to 28% moisture content of the grain, after drying, resulted in maximum grain yield and the highest percentage of head rice yields. In the 1940's and 1950's McNeal (1950) of Arkansas showed that the highest milling quality of dried paddy rice occurred when the grain was threshed between 16 to 24% moisture content. Kester et al. (1963) of California showed in the 1960's that the highest head rice yield after drying, was obtained at harvest moisture contents between 25 to 32%. Also, Morse et al. (1967) of California showed that the maximum head rice yield was obtained when the grain was harvested between 28-30% moisture content. In the 1970's Calwooder et al. (1980) of Texas found that the percentage of total milled rice increased with delays in harvest date but the percentage of head rice reached a maximum at an intermediate harvest date then declined rapidly with delays in harvesting.

Dilday (1987) showed significant differences between cylinder speed, germlasm, and moisture content of the grain at harvest on milling yield. For example, the percentage of broken kernels approximately doubled when the cylinder speed of the thresher was increased from 600 to 1000 RPM. 'Newbonnet' produced the fewest broken kernels (5.7, 11.0) while 'Lemont' had the most broken kernels (22.6, 30.6) at 600 and 1000 RPM, respectively. Also, 'Lemont' produced the highest total milling yield (69.5, 70.6); whereas, 'L202' produced the lowest total milling yield (63.4, 66.3) at 600 and 1000 RPM, respectively.

The objective of this study was to determine the affect of nitrogen fertilizer on milling quality of two rice cultivars, Lemont and Newbonnet.

MATERIALS AND METHODS

Nitrogen fertility experiments were conducted during a two-year period, 1986 and 1987. Field trials with two cultivars were conducted at the Rice Research and Extension Center Stuttgart, Arkansas, on a Crowley silt loam soil which is a fine montmorillonitic, thermic Typic Albaqualf. The experimental design for each of the tests was a randomized block design with four replications. Rice was drill-seeded in plots that were 14 row wide and 4.57 m long with a 0.191 m row spacing on April 23, 1986 and 1987. The seedlings emerged on May 4, 1986 and May 8, 1987, respectively. Plots of the two cultivars were harvested each year at 10 separate harvest dates. Harvesting started at a moisture content of approximately 25% and the harvest continued twice a week for five weeks. The number of days after heading was noted for each harvest sample.

A single row 3.66 m long was hand-harvested from the center 10 rows of each plot generally between the hours of 1100 and 1400 when the kernels were free of dew and surface moisture. The outer 2 rows on each side of each plot were not harvested. The amount of rice harvested from the 3.66 m row generally ranged from 450 to 750 grams. A Vogel thrasher (Mention of trade names or proprietary products if for information only and does not necessarily imply their endorsement by the USDA, Rice Land Cooperative, or the Arkansas Agric. Exp. Stn.) was used to separate kernels from straw. The samples were passed through a screen to remove the larger leaves and stems. Samples were weighed in the laboratory and the moisture content was determined with a DICKEY-john Model Gac II grain analysis moisture meter. The samples were immediately placed in a zipper-top plastic bag and taken to Riverland Cooperative, Stuttgart, Arkansas the following day for drying to about 12% moisture and analysis. Samples were cleaned over a Carter-Day dockage machine with FGIS approved sieves and determinations of milling yield were carried out in accordance with the standard procedure of rice graders (Anonymous, 1982, 1983), (Smith, 1972), except that the samples processed were smaller (152 g) than the normal 1,000 grams.

The test plots were flashed two times in 1986 and three times in 1987 to obtain uniform seedling emergence and a permanent flood (5-10 cm) was established at about the fifth true leaf stage and maintained until maturity. The four nitrogen treatments were 0, 3-way split, 6-way split and all preflood. A total of 135 and 180 lbs./A of nitrogen were applied as urea to Newbonnet and Lemont, respectively. The 3-way split application of nitrogen was applied at the rate of 75-30-30 and 120-30-30 lbs./A of nitrogen on Newbonnet and Lemont, respectively. The 75 and 120 units were applied prior to the first flood, the first 30 units at 1/2 to 1 internode elongation and the second 30 units were applied 10 days later. All of the nitrogen was applied immediately prior to the first flood in the preflood treatment. Head rice, total milled rice, and percentage of broken kernels for each cultivar were analyzed using the General linear models procedure. The LSD procedure was used for mean separation.

RESULTS AND DISCUSSION

The combined analysis (Table 1) for 1986 and 1987 showed that the greatest percentage of broken kernels and the lowest head rice yields occurred when no nitrogen fertilizer was applied. Conversely, the fewest broken kernels and the highest head rice yields were obtained when nitrogen fertilizer was applied. Furthermore, the fewest broken kernels were observed when all of the nitrogen was applied at preflood in both 1986 and 1987. Also, the greatest head rice yield was obtained where all of the nitrogen was applied at preflood in 1987. The greatest numerical head rice yield also occurred where all of the nitrogen was applied at preflood in 1987.
Table 1. Influence of Nitrogen Fertilizer on Milling Yield (Combined analysis - Lemont and Newbonnet)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>1986</th>
<th>1987</th>
<th>1986</th>
<th>1987</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head Rice</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Broken</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>59.8 b</td>
<td>43.4 c</td>
<td>10.4 a</td>
<td>25.4 a</td>
</tr>
<tr>
<td>1-way split</td>
<td>61.9 a</td>
<td>53.4 b</td>
<td>7.2 b</td>
<td>15.7 c</td>
</tr>
<tr>
<td>6-way split</td>
<td>61.7 a</td>
<td>51.4 b</td>
<td>8.0 b</td>
<td>18.0 b</td>
</tr>
<tr>
<td>All Preflood</td>
<td>62.2 a</td>
<td>57.1 a</td>
<td>6.8 c</td>
<td>13.0 d</td>
</tr>
</tbody>
</table>

Means within a column followed by the same letter are not significantly different at the P < 0.05.

Table 2. Influence of Nitrogen Fertilizer on Milling Yield of Lemont.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>1986</th>
<th>1987</th>
<th>1986</th>
<th>1987</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head Rice</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Broken</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>55.9 c</td>
<td>35.0 d</td>
<td>15.2 a</td>
<td>33.3 a</td>
</tr>
<tr>
<td>1-way split</td>
<td>60.5 b</td>
<td>52.0 b</td>
<td>8.7 b</td>
<td>18.5 b</td>
</tr>
<tr>
<td>6-way split</td>
<td>61.2 ab</td>
<td>49.3 c</td>
<td>8.9 b</td>
<td>21.4 c</td>
</tr>
<tr>
<td>All Preflood</td>
<td>62.1 a</td>
<td>56.8 a</td>
<td>7.3 c</td>
<td>14.2 d</td>
</tr>
</tbody>
</table>

Means within a column followed by the same letter are not significantly different at the P < 0.05.

Table 3. Influence of Nitrogen Fertilizer on Milling Yield of Newbonnet.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>1986</th>
<th>1987</th>
<th>1986</th>
<th>1987</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head Rice</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Broken</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>63.7 a</td>
<td>51.7 d</td>
<td>5.6 ns</td>
<td>15.6 a</td>
</tr>
<tr>
<td>1-way split</td>
<td>62.9 ab</td>
<td>55.6 b</td>
<td>5.7</td>
<td>13.0 c</td>
</tr>
<tr>
<td>6-way split</td>
<td>62.6 ab</td>
<td>53.3 c</td>
<td>5.5</td>
<td>14.6 b</td>
</tr>
<tr>
<td>All Preflood</td>
<td>61.8 b</td>
<td>57.3 a</td>
<td>6.2</td>
<td>11.9 d</td>
</tr>
</tbody>
</table>

Means within a column followed by the same letter are not significantly different at the P < 0.05.

applied at preflood in 1986 but the preflood treatment was not significantly different from the 3-way or 6-way split applications.

Data from each cultivar, Lemont and Newbonnet, were analyzed independently and the analysis showed that the highest percentage of broken kernels in Lemont occurred when no nitrogen was applied and the fewest broken kernels occurred where all of the nitrogen was applied at preflood both in 1986 and 1987 (Table 2). Also, the lowest head rice yield occurred where no nitrogen was applied both in 1986 and 1987. The highest head rice yields in 1987 occurred where all of the nitrogen was applied at preflood; furthermore, the largest numerical head rice yield in 1986 was where all of the nitrogen was applied at preflood but the preflood treatment was not significantly different from the 6-way split. There was no significant difference among nitrogen treatments for broken kernels in Newbonnet in 1986 but in 1987 the zero and all preflood treatments caused the milling yield of Newbonnet to react the same as the milling yield for Lemont in 1986 and 1987 (Table 3). Furthermore, the head rice yields of Newbonnet and Lemont reacted the same for all four treatments in 1987. The greatest head rice yield of Newbonnet occurred at the zero level of nitrogen in 1986 and there were no significant differences among the treatments where nitrogen was applied. The 1986 head rice yield data for Newbonnet was not consistent with the head rice yield data for Lemont in 1986 and 1987 or for Newbonnet in 1987. This suggest that further studies are needed to delineate the effects among nitrogen treatments on head rice yields, especially for Newbonnet.

Non uniform applications of nitrogen fertilizer (steering), which are usually due to improper aerial applications, are common in producer fields of rice. Furthermore, uneven distribution of nitrogen fertilizer can have an adverse effect on milling yield in rice. For example, these data show that the percentage of broken kernels will approximately double when no nitrogen is applied as compared to proper nitrogen application at preflood or in split applications, especially for Lemont. Also, these data suggest that Newbonnet reacts in the same manner as Lemont, although the affect of increasing the percentage of broken kernels in the streaked (no nitrogen) area will not be as pronounced in Newbonnet as it is in Lemont, a variety which requires a higher level of nitrogen for maximum grain yields (Norman and Wells, 1985).

**SUMMARY**

These data show that nitrogen fertilizer has an influence on milling yield in rice, especially on Lemont. Furthermore, these data show that the percentage of broken kernels can essentially double, especially for Lemont (14 to 33%), in those areas of the field which receives no nitrogen as compared to areas that receive all of the nitrogen at preflood or in split applications. The percentage of broken kernels of Newbonnet (12 to 16%) were affected about like the percentage of broken kernels of Lemont but the affect was not as pronounced. Also, the head rice yield can be reduced by as much as 7-22% percent for Lemont in areas where zero nitrogen is applied as compared to all of the nitrogen being applied at preflood or in split applications.

**ACKNOWLEDGEMENTS**

The assistance of D. W. Bickerstaff and T. R. Hays, Vice-President-Commodity Operations and Manager-Appraisal Office, respectively, for RiceLand Cooperative, Stuttgart, Arkansas for the grain drying and analysis of the rice samples is gratefully acknowledged.

**LITERATURE CITED**


RESPONSE OF FISH COMMUNITIES TO HABITAT ALTERATION IN A SMALL OZARK STREAM

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ABSTRACT

From 1984 to 1986, the Arkansas Highway and Transportation Department reconstructed and upgraded a portion of St. Hwy. 123 west of St. Hwy. 7 at Pelsor, Arkansas. As a result of the construction, portions of Haw Creek, Johnson County, Arkansas, a third order stream in the Boston Mountains Ecoregion, were straightened and channelized. In reconstructing specific stream reaches, stream banks were rip-rapped and vegetated, gabions constructed and positioned, stream substrates and pool-riffle ratios altered. Intermittent and riparian habitat and fish biomass and diversity in altered reaches were radically altered. Channelized reaches became wide and shallow, lacking overstory cover and pools. Substrate particle size changed from boulder/rubble to rubble/gravel/sand and velocity increased. Fish communities in channelled reaches simple; Campostoma anomalum, Notropis boops, and Etheostoma spectabile accounted for more than 80 percent of all fish captured. This represented a shift from piscivore and insectivore-placivore to herbivore and insectivore dominated feeding guilds. Natural channel reaches had more complex fish communities and greater abundance of centrarchids and ichthyids, primarily deeper water groups. Immediately after channelization, altered reaches had a larger biomass than natural reaches (0.43–0.26 g/m²). The summer following alteration, channelled segments were basically dewatered, and biomass decreased dramatically (0.06–0.11 g/m²). One year post channelization, altered reaches had eroded, scoured and deepen at their headwaters, and embedded. Fish community composition in altered reaches stabilized to a riffle-type assemblage dominated by the herbivore Campostoma anomalum.

INTRODUCTION

Stream channelization is one of the most destructive activities that man imposes on riparian ecosystems. Over 300,000 km of stream channels have been modified in the United States (Schoof, 1980). Specific impacts of channelization upon stream ecosystems are multidimensional and interrelated. Two aspects of channelization of prime importance are habitat changes due to channelization and the resulting biological response.

Hubbard et al. (1988) in their review of channelization listed gradient, velocity, depth, channel meander, flow regime, substrate, instream structure, temperature, turbidity, water chemistry, and terrestrial and riparian habitats as being affected by channel alteration. Immediate impacts on instream and riparian biota result from the physical destruction of the biota and their habitat. Delayed impacts may occur as habitats continue to be altered due to land use changes or unstable conditions. The magnitude and duration of particular impacts depend on the type of stream system involved, length and timing of channelization, and the impacted biological species.

Early studies of channelization effects on fishes were conducted by Schneberger and Funk (1971), Barton et al. (1972), Wilkenson (1973), and Moyle (1976). More recently, channelization impacts on fish have been well documented, but mitigation of losses has not been adequately addressed (Edwards et al., 1984).

Channelization and subsequent shifts in fish species composition were identified as early as the 1900's (Shelford, 1911; 1917). Trautman and Gartman (1974) reported that during an 86-year period, relative abundance of fishes in Gordon Creek, Ohio, decreased and the fish fauna reverted from smallmouth bass associations to typical headwater or brook associations comprised of beach-nosed dace, red-sided dace, creek chub and silver-jawed minnow. The decrease was attributed to dredging, channelizing and clearing that occurred before the turn of the century. Smith (1960, 1971) reported similar results from Illinois. Biomass and number of fish species have been found to be reduced in channelized streams. Golden and Twilley (1976) reported downstream reduction in game and fish species and biomass, especially centrarchids, while greater numbers of nongame fish were evident where channelization removed riffles and instream cover. Schlosser (1982) noted more stable trophic structure, biomass, and age structure in fish communities of a natural headwater stream when compared with a similar modified stream. He noted that seasonal and annual variations in fish biomass and trophic structure occurred in the modified stream because of shifts in both amounts and types of instream production. Large pools in the natural stream increased habitat volume and stability relative to the modified stream. This resulted in a trophic structure of predominately large insectivore-piscivore and benthic insectivore fish species. Trophic structure, age structure, and recruitment were stable in the natural stream.

Bayless and Smith (1964) evaluated fish populations in 23 channelized streams and 36 proximate natural streams in eastern North Carolina. Comparisons indicated that reductions in the magnitude of 90 percent occurred both in weight of game fish per acre and in number of game fishes over six inches total length per acre, and following channelization no return towards natural stream populations had occurred within a 40 year period.

Spawning of fishes dependent on bottom substrate can be severely altered by channel modification. Bowman (1970) showed that slight differences in bottom grain distribution in channels resulted in marked segregation of spawning distribution of three species of redhorse. Grain size has been considered a spawning stimulus, and lack of suitable grain size or proper spatial grain configuration may result in lack of egg maturation, behavior alterations impeding spawning, and egg resorption (Simpson et al., 1982).

Flow or substrate alteration due to channelization may cause reduced spawns of species utilizing bottom material to deposit their eggs. Darters and sculpins actively use substrate for reproduction. Channel modification may remove suitable spawning sites, thereby forcing substrate spawners to move either up or downstream, use less suitable substrate, or not to spawn at all and to resorb eggs (Simpson et al., 1982).

This investigation tested the hypothesis that stream fishes inhabiting a third order stream in the Boston Mountains Ecoregion of Arkansas are reduced in biomass and diversity by channel alteration; that fish biomass and diversity will change in altered reaches over time; and that altered reach instream habitat will return to pre-channelization conditions.
STUDY AREA

Haw Creek lies in northwestern Arkansas, draining an area of approximately 200 km². The stream, located in the Boston Mountains Ecoregion, flows in a southeasterly direction for 13 km, attaining third order before entering Big Piney Creek. The majority of the drainage basin is sandstone substratum covered by oak-hickory forest and pasture. Continuous flow in the headwater reaches is dependent on extended rainfall. Intermittent flow is characteristic from July through November.

Stream channels in Haw Creek are fluvially-formed, alluvial, riffle-pool structure from headwaters to third order. Shallow, slow flowing pools alternate with short, shallow swift riffles. Gravel is concentrated in riffle areas and slopes of pools, while pool bottoms are predominately bedrock-rubble.

MATERIALS AND METHODS

Quantitative fish samples were collected in third order reaches of Haw Creek, Johnson County, Arkansas. Pools and riffles were visually inspected, measured, then partitioned based on depth, flow, and substrate. Small mesh block nets were placed at the ends of each area to prevent fish movement in and out of the study area. Fishes were captured by electroshocking with a generator coupled to a variable voltage pulsatuar (Coffelt VVP-2C) and hand held electrodes. A minimum of three electroshocking runs was conducted at each site. Specimens were preserved in 10% formalin in the field. Upon return to the laboratory, fishes were identified to species utilizing taxonomic identification keys of Buchanan (1973), weighed, measured, preserved in 50% isopropanol and catalogued.

Population size for each species was estimated. Areas were compared for fish community distribution and partitioning. All species were grouped by feeding guilds based on Pflieger’s (1975) general description of food habits. Structure of the fish community at each site and habitat type was summarized using percentage composition of biomass by species and by feeding guild.

Quantitative habitat analysis were performed using methods developed by Ebert et al. (1987b) and Platts et al. (1987). Water quality and velocity analyses and channel typing were conducted at each sample site following the methods of Standard Methods (1975), Patton (1987), and Rosgen (1985).

RESULTS

A total of 1826 individuals comprising six families and fourteen species were represented in electrofishing samples (Table 1). Although channelized reaches had fewer species (6-10/15), biomass was greater immediately after channelization compared with that of natural reaches (0.57-0.69/0.47-0.59 g/m²). Fish biomass in altered reaches did not show an increase with time, but returned to approximate natural reach levels 2 years after channelization (0.43-0.58/0.44-0.51 g/m²) (Table 2). Mean length and weight per individual was also greater in natural reaches. Darters (Percidae), and stonerollers-shiners (Cyprinidae) dominated altered reaches (67-98%) and comprised a substantial percentage, by number, of natural reaches (48-77%). Sunfishes (Centrarchidae) and catfishes (Ictaluridae) were abundant in natural reaches (23%).

Dominant feeding guilds in altered reaches were herbivores and insectivores, while natural areas were dominated by insectivores, insectivores-piscivores, and omnivores (Table 1). *Comastoma anomalum*, a herbivore, was the most numerous species collected at all sites, and was primarily concentrated in natural riffles and altered reaches. *Etheostoma blennoides*, *E. spectabile* and *Noturus exilis*, insectivores, were also abundant in natural riffles. Smaller individual sizes of *E. spectabile* were consistently collected in altered riffles. *Lepomis cyanellus*, *L. megalotis*, and *Micropterus dolomieu*, insectivores-piscivores; *Notropis boops*, insectivore; and *Pimephales notatus*, omnivore; dominated natural areas.

Study areas differed greatly in channel and water width, depth, substrate particle size, and length (Table 3). Channelized reaches were smaller in area, shallower, swifter, and had a more homogenous substrate than did natural reaches. Channel width was similar in all areas. Size of substrate was substantially less in altered reaches. Dissolved oxygen and specific conductance values were similar among study sites. Stream bank erosion was moderate, and canopy closure and instream cover were lacking in altered reaches.

DISCUSSION

Stream fish biomass, species number and species composition have been found to decrease with channelization (Bayless and Smith, 1964; Smith, 1968 and 1971; Trautman and Gartman, 1974; Golden and Twilley, 1976; and Schlesser, 1982). Increase in species number in streams, attributed to addition rather than replacement of species, or as a stream progresses from its headwaters to its mouth. Increase in species diversity has been found to be directly related to habitat variability (Horwitz, 1978). When channelization alters a stream, decreases in both number and diversity of fishes are characteristic. In biologically diverse streams, such as Haw Creek, distribution of fish has been found to be correlated with instream habitat (Schlesser, 1982; Ebert et al., 1987) and constrained by environmental tolerances (Smith and Powell, 1971) and habitat and foot preferences (Mathews and Hill, 1979a, 1979b; Orth and Maughan, 1984). In our investigation altered reaches failed to provide the habitat requirements of numerous species, primarily centrarchids and icthyodids. This compares with results documented by Lotrich (1973). Populations of sport fish, such as largemouth bass, have been directly related to stream reaches with a higher proportion of pools (Wydoski and Heim, 1980). Shallow riffle species, characterized by *C. anomalum* and *E. spectabile*, were more abundant in altered reaches of Haw Creek than in natural channels. Todd and

<p>| Table 1. Species list for third order reaches of Haw Creek, Johnson County, Arkansas (1 = herbivore-detrivore; 2 = omnivore; 3 = insectivore; 4 = insectivore-piscivore). |
|---|---|---|---|
| Species | Classification |
| Cyprinidae | | | |
| <em>Comastoma anomalum</em> | 1 | | |
| <em>Notropis boops</em> | 4 | | |
| <em>Pimephales notatus</em> | 4 | | |
| Catostomidae | | | |
| <em>Lepomis cyanellus</em> | 1 | | |
| <em>Lepomis megalotis</em> | 1 | | |
| <em>Micropterus dolomieu</em> | 1 | | |
| Ictaluridae | | | |
| <em>Ictalurus natalis</em> | 3 | | |
| <em>Noturus exilis</em> | 3 | | |
| Table 2. Fish biomass (g/m²) and numbers for channelized and natural sample reaches of Haw Creek, Johnson County, Arkansas. |</p>
<table>
<thead>
<tr>
<th>Reach</th>
<th>Channelized</th>
<th>Natural</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spring 1986</td>
<td>0.57-0.69</td>
<td>0.47-0.59</td>
</tr>
<tr>
<td>Summer 1986</td>
<td>0.06-0.11</td>
<td>0.23-0.27</td>
</tr>
<tr>
<td>Fall 1987</td>
<td>0.46-0.56</td>
<td>0.26-0.28</td>
</tr>
<tr>
<td>Summer 1987</td>
<td>0.11-0.19</td>
<td>0.44-0.51</td>
</tr>
</tbody>
</table>

* fish biomass (g/m²) (top) and numbers (bottom) determined by area of wetted perimeter (available habitat) per sample.
Response of Fish Communities to Habitat Alteration in a Small Ozark Stream

Table 3. Physical and chemical parameters for channelized and natural reaches (3rd order) of Haw Creek, Johnson County, Arkansas.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Reach 1</th>
<th>Reach 2</th>
<th>Reach 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel</td>
<td>S</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>Width (m)</td>
<td>18.2</td>
<td>18.8</td>
<td>19.8</td>
</tr>
<tr>
<td>Water</td>
<td>19.3</td>
<td>18.7</td>
<td>19.5</td>
</tr>
<tr>
<td>Max.</td>
<td>0.3</td>
<td>0.4</td>
<td>0.4</td>
</tr>
<tr>
<td>Depth</td>
<td>1.3</td>
<td>1.6</td>
<td>1.4</td>
</tr>
<tr>
<td>Substrate</td>
<td>19.5</td>
<td>19.5</td>
<td>19.5</td>
</tr>
<tr>
<td>Length (m)</td>
<td>3.3</td>
<td>3.1</td>
<td>3.1</td>
</tr>
<tr>
<td>Dissolved</td>
<td>*</td>
<td>9.9</td>
<td>9.9</td>
</tr>
<tr>
<td>Oxygen (mg/l)</td>
<td>7.9</td>
<td>8.1</td>
<td>8.1</td>
</tr>
<tr>
<td>Conductivity</td>
<td>79.0</td>
<td>82.0</td>
<td>82.0</td>
</tr>
<tr>
<td>Canopy</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Gloomer</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Biomass</td>
<td>19.5</td>
<td>19.5</td>
<td>19.5</td>
</tr>
<tr>
<td>(S &lt; Spring; Slummer; F=Fall) (g=gravel; cb=cobble; bd=bedrock)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Stewart (1985) found primary food items of E. spectabile to be mayflies, chironomids, amphipods and ostracodes, all of which are plentiful in shallow riffle areas. Abundance of C. anomalum has been suggested by Brown and Todd (per. comm.) to be influenced by abundance of periphyton on shallow riffle substrate in the Illinois River, Washington County, Arkansas. This species is considered to be herbivorous (Pflieger, 1975; Sewell et al., 1980; Orth and Maughan, 1984). Channelized reaches of Haw Creek had abundant periphyton coverage on all instream substrate due to shallow depth and lack of overhead cover, both of which allow more solar radiation to reach the stream substrate. C. anomalum was the most abundant fish collected in channelized reaches, accounting for 56 to 67 percent of total numbers of individuals.

In our investigation, it is apparent that channelization not only reduced fish biomasses and numbers in altered reaches (Table 2), but also reduced species composition and biased altered reach fish populations towards smaller individuals. These are capable of withstanding shallow water conditions. Triantafillou and Gartman (1974), reporting on Gordon Creek in Ohio, and Schlosser (1982), reporting on a natural headwater stream in east central Illinois, noted total population shifts and apparent size reductions of groups resulting from channel modifications. It is important to note that altered reaches of Haw Creek were bordered by natural areas, thus offering refugia to many species, especially centrarchids and ictalurids. Ebert et al. (1987a), in their quantification of habitat requirements for eight species of Ozark fishes in streams within the Ozark-St. Francis National Forests, noted that E. spectabile, C. anomalum, and N. exilis, and juvenile life stages of L. megalotis, L. cyanellus and M. dolomieu preferred shallow, fast/slow riffles with a gravel dominated substrate. In their investigation, N. boops was primarily a shallow pool species and adult L. megalotis, L. cyanellus, and M. dolomieu preferred deep, moderately flowing pools with bedrock/bedrock substrate. Channel alteration in Haw Creek resulted in shallow, slow/moderate flowing gravel dominated reaches which offered preferred habitat to darters and stoners. Natural stream reaches with an abundance of debris and boulder dominated pools were preferred by centrarchids and ictalurids.

During low summer flows in 1986 and 1987, altered reaches of Haw Creek were practically dewatered. This occurrence is common in many Ozark streams. Fish biomasses in altered reaches during these periods are greatly reduced (0.12-0.21 g/m²) compared to natural reaches (0.22-0.26 g/m²). This may be a result of suitable instream cover loss and an overall reduction of wetted area in altered reaches. Ebert et al. (1987a) found a strong correlation between wetted area (m²) and total fish weight (r² = 0.94) and wetted area (m±) and total fish numbers (r² = 0.61) in 10 streams in the Boston Mountains Ecoregion of Arkansas, sampled from 1985 to 1987. Their investigation indicated that fish numbers and weight would inrease with wetted area until an inflection point was reached, based on channel form, where water levels above the point would result in no significant additional usable fish habitat. This is one of the basic tenants of many instream methods used to reserve water for stream fisheries and aquatic ecosystems (Filipek et al., 1987). Two years after channelization altered channels were scouring. Rubble/boulder material that moved into the altered reaches during storm events had diversified the bottom substrate, and fish populations during normal flows were comparable to those of natural channels (Table 2). In two altered reaches scour pools were formed where natural reaches entered the areas. However, this is often offset by silt deposition downstream of the scouring, channelized area (Yearke, 1971). It is apparent that with time the altered reaches will return to a natural state. This is due in part to the altered reaches being bounded by natural areas and to the small overall length of each altered reach (>1 km). Previous long term studies have indicated an irreversible destruction of stream habitat and fish populations in channelized streams. Tratman and Gartman (1974) reported that after 86 years relative abundance of fish in Gordon Creek, Ohio, was decreased and diversity altered. Bayless and Smith (1964) reported fish populations in 23 channelized streams and 36 proximate natural streams in eastern North Carolina had reductions in the magnitude of 90 percent in number and weight of game fish following channelization, with no return towards natural stream populations over a 40 year period. Also, the physical loss of habitat and loss in ectonc, both aquatic and terrestrial, can occur above and below the channelized section, expanding the area impacted by channelization (Simpson et al., 1982).

This investigation indicated that small Ozark stream fish populations and habitat can recover from channelization if altered reaches are short in overall length and bounded by natural undisturbed areas. There was a direct tendency for darters and stoners to seek the shallow, slow/moderate flowing, gravel substrate of altered reaches. The stimulus for the new habitat colonization may be related to preference for that type of habitat: or for abundant food organisms. Large size fishes were excluded from altered reaches due to depth and cover limitations. Channelization of natural stream reaches should be avoided in highway construction and improvement if possible because of major impacts, not only to the aquatic system, but also to the terrestrial environment and its associated wildlife (Hedrick, 1975). Further, upstream channelization has caused engineering problems, such as increased bank and bottom erosion, increased frequency of floods, and a higher incidence of downstream bridge repair due to the above factors (Emerson, 1987).

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LITERATURE CITED


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Response of Fish Communities to Habitat Alteration in a Small Ozark Stream


FORESTRY ON THE ISLAND OF TAIWAN, ROC -
THE STATE OF THE ART

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ABSTRACT

The forests of Taiwan vary from lush subtropical vegetation to subalpine coniferous associations. Topography is exceedingly rugged, and stands border on the verge of silvicultural inoperability. In the 1950s and 1960s, the wood products industry in the Republic of China was of paramount importance; the production of high-quality sawtimber from old-growth cypress (Cupressaceae) stands provided the financial capital that built one of the most prosperous national economies in the modern world. In the 1980s, forestry in Taiwan is a curious blend of old methods and new technologies, as modern silvicultural practices are applied to reforest over-crowded stands, to harvest and reproduce remaining old-growth stands, and to expand the silvicultural importance of other forest types on the island. Many applied research efforts would be promising in application to the forests of Taiwan, such as long-term studies of silvicultural practices on water quality, methodology of natural regeneration applied to cypress and *Taiwania cryptomerioides* (Taxodaceae), uneven-aged regulation applied to bamboo, *Phyllostachys pubescens* (Bambusaceae), growth and yield in coniferous plantations, effectiveness of modern herbicides in controlling competition in young plantations, and application of contemporary economic assessments in the evaluation of silvicultural alternatives.

INTRODUCTION

During the past 20 years, a number of forestry scientists and officials from the U.S. and Taiwan have participated in exchange programs to visit and observe forestry programs within the universities, government agencies and industries of the two nations. Among the U.S. representatives, the Department of Forest Resources at the University of Arkansas at Monticello (UAM) has played a significant role. Dr. T.T. Ku was invited to participate in the Sixth National Reconstruction Conference in Taiwan in 1975, and served as a Visiting Professor at the National Taiwan University in 1983 (Ku, 1983) supported by Taiwan’s National Science Council. In the late 1970s, and again in the mid-1980s, a number of forest scientists and high-level forest administration officials from Taiwan came to study the operations of the U.S. Forest Service and forest industries in the U.S., including Arkansas.

This decade of cooperation resulted in an international research accord between the University of Arkansas (UA) and the Council of Agriculture (COA) of Taiwan. The agreement was initiated with an international symposium on Forest Productivity and Site Evaluation held in Taipei in the Fall of 1987 (COA, 1987). Over 20 papers, including eight by the authors of this article, were presented to more than 90 scientists representing 15 governments and private agencies from the two countries. However, the symposium was only the centerpiece of a 2-week adventure that included eight days of field tours to observe forest practices and management operations in the southern central and northern sections of Taiwan. This paper reports on those observations.

GEOGRAPHY

Taiwan is located along the fringe of the continental shelf of Asia, on the western border of the Pacific Ocean. It is about 395 kilometers long and 145 kilometers at its broadest width near the central portion of the island. The principal mountain system runs north-south with its highest peak, Mount Jade (Yushan), standing at 3,997 meters near the center of Taiwan. The Tropic of Cancer bisects the island and confers upon it a tropical and subtropical climate. Annual rainfall ranges from 1,000-67,000 millimeters and averages 2,600 millimeters; the average annual temperature is 22°C. An excellent overview of the physiography and climate can be found elsewhere (Liu, 1976, 1987).

Over 52 percent of its land area is in forests at the present time, with biomes ranging from tropical hardwoods in the coastal low elevations to the humid, montane coniferous forests at the higher elevations. The present population of nearly 20 million people has brought a socioeconomic impact to forest policy. The objective in forest resource management over the past years has shifted from timber production in the 1960s to soil and water conservation in the 1970s, and to recreation and environmental preservation in the 1980s.

ECOLOGICAL ZONES

Liu (1976) identified four major ecological zones on the island of Taiwan based primarily on an elevation gradient; these are the subalpine, cool-temperate, warm-temperate, and tropical zones. The extremely rugged topography, high rainfall accentuated by local orographies, and variability in temperatures result in highly heterogeneous climatic and ecological conditions within each zone. Geologically, soils are quite young with the notable exception of the tropical ultisols and oxisols in the lowlands. Important forest soils on the island include the spodosols at higher elevations (1800 meters and higher), affisols, inceptisols, and the lithosolic entisols associated with recent landslide activity (Shen, 1987).

Six ecologically-derived forest formations have been recognized (Liu, 1987). These closely correspond with five silvicultural regions, identified by combining the gradients of elevation and temperature with species that are of commercial importance (Kuo, 1987). There are two major distinctions between the ecological and silvicultural classification. First, the division of forestry and agriculture is found at approximately 500 meters (Chen, 1957). Secondly, the lowland littoral ecosystems have little value for commercial timber production.

The subalpine coniferous forest is the uppermost forest of the country, dominated by Taiwan fir (Abies spp.) and alpine juniper (*Juniperus chinensis* Linn. var. *kuzusa* Hort. ex. Endl.). It occupies the highest elevations in the country and is characterized by the coldest temperatures. This forest type is not commercially productive, but is extremely important in the stabilization of high slopes.

The cold-montane coniferous forest is a mixed forest dominated by Taiwan hemlock (*Tsuga chinensis* var. *formosana* [Hay.] Li et Keng), Taiwan spruce (*Picea morrisonica* Hay.), Taiwan red pine (*Pinus taiwanesis* Hay.), and Taiwan armand pine (*Pinus armandii* Fr. var. *melianthus* [Hay.]). This forest type is found between 2000-3000 meters, and is transitional between the types above and below. It is of minor commercial importance.
The warm-temperate montane coniferous forest and warm-temperate montane rain forest are intermingled through altitudes of 700-2500 meters. Generally, the coniferous type occupies the higher elevations, and the hardwood rain forest the lower elevations. Occurrence varies greatly due to local variations in soils, topography, and incidence of precipitation.

The conifers of the warm-temperate montane forest are the backbone of the timber economy in the Republic of China. The species of paramount commercial value are red cypress (Chamaecyparis formosensis Matsum.) and yellow cypress (Chamaecyparis obtusa var. formosana [Hay.] Rehd.). In addition, other conifers of commercial importance in this region are China fir (Cryptomeria japonica D. Don.)

Over 200 species of hardwood characterize the warm-temperate montane rain forest. The most important of these is Zelkova (Zelkova serrata [Thunb.] Mak.), a member of the Ulmaceae with utility similar to that of oak. In addition, the bamboo resource reaches its zenith in this type. The island has over 60 species of bamboo, of which the most usable is moso bamboo (Phyllostachys pubescens Mazel.). Moso bamboo is valuable both as an ubiquitous construction material and a source of food in bamboo shoots.

The tropical rain forest of Taiwan has been largely cutover and converted to agriculture. The high rainfall, low elevation, moderate topography, and warm year-round temperatures promote activities other than forestry. The second-growth species composition includes general (Ficus, Trema Macaranga, Mallotus, and Bischofia spp.) common to the second-growth rain forests of Indomalaysia (Liu, 1987).

The littoral forest is found at the lowest elevations along the coastline. The mangrove forests of the island are similar in structure and composition to mangroves throughout the tropics. Strand forests are common to seashores in the southern part of the island. In a manner similar to the tropical rain forest, the littoral forest of Taiwan is primarily of ecological significance rather than of value as a raw resource material for manufactured forest products.

**DEVELOPMENT OF FORESTRY IN TAIWAN**

Forestry has been practiced in Taiwan for over 100 years, beginning with the Japanese occupation of the island in 1895, carrying through the liberation in 1945 with subsequent establishment of the Chinese government, through the present day (Kuo, 1987). Early forest operations were primarily timber mining, as was the case in the United States. In his classic work, Fernow (1913) wrote that the Japanese established an administrative structure for the practice of forestry in the home islands, but exploited the timber resources on the island that was then known as Formosa, a Portuguese word meaning the Island Beautiful or the Fantasy Island. The most valuable species sought in the region were Japanese fir and yellow cypress, with mention of a species of "Zelkova" [sp] (Fernow, 1913).

Modern forestry became prominent after the establishment of the Chinese government in 1945. The major capital assets of the island at that time were its forests, particularly yellow cypress and red cypress. Lumber produced from these species is of exceptional quality and value, and provided much of the financial basis for the government in the 1950s and the early 1960s. With the vigorous growth in the economy due to high-tech industry, and the resulting increase in the standard of living, the demand for non-commodity natural resources has increased to a level that has begun to dictate the current character of resource management. In essence, forestry operations have changed from timber production in the 1950s to the present status of emphasis in research and preservation.

**CONTEMPORARY FORESTRY OPERATIONS**

Harvest of timber in Taiwan is usually followed by the establishment of plantations. At low elevations (800-1,000 meters), hardwoods such as Zelkova and other endemic species, as well as the exotic Leucaena leucocephala (Lam.) deWit, are planted at 2 x 2 meter spacings. This dense spacing is important in reducing both competition of weed species and branchiness of the desired species. Underplanting of Zelkova with other species such as nitrogen-fixing Acacia spp. is done both to promote plantation diversity and to enhance the nutrient status of the site.

At higher elevations (1,500-2,500 meters), harvest is followed by establishment of plantations of the native China fir, Taiwania, the yellow and red cypresses, and the exotic Japanese fir. Seedlings are usually planted at 2 x 2 meter spacing. However the growth and yield that can be expected from these stands are not certain, particularly from recently adopted species.

Planting stock is produced as a two-year-old seedling; after the first year seedlings are transplanted to a polyethylene bag holding about 1,500 cm³ of soil, and spend a second year in the nursery prior to planting. At higher elevations, plantation spacings may vary depending on the topographic severity of the site. On reasonably flat sites (less than 30° slope), spacing within the row and between rows may vary from 2 to 3 meters. On steep slopes, seedlings are planted as a linear clump of three or four trees within a meter; approximately 5 meters separate the clumps within the row, with rows 3 meters apart. This unique practice is easier to implement on steep slopes, promotes desirable form in crop trees, and improves the efficiency of competition control.

Natural regeneration is an increasingly common practice, especially with the more tolerant red and yellow cypress. Two silvicultural systems are frequently employed, with the new stand originating either as advance growth or by means of seed fall from adjacent stands. The uniform seed tree method is also employed, though the sites are frequently inaccessible for seed tree removal. A third alternative that was observed is a classic textbook variation of the seed tree method known as the group seed tree method, where seed trees are left as isolated groups. This practice promotes windfall resistance of the seed trees, and also allows operational harvest of the seed trees associated with early pre-commercial or commercial thinning.

Competition control is a critical aspect of stand establishment in the warm-temperate and subtropical environment. The standard method of weed control is by means of manual labor. Woods workers typically use small scythe-like knives to cut swaths amid the competing vegetation within which seedlings can develop. Between 17 and 20 such treatments are applied in the first 10 years of plantation development; three treatments per year are required in the first three growing seasons. Because of such intense labor requirements as well as the logistic support required for these workers at high elevations, the present net value of plantation establishment in the coniferous forest varies from U.S. $2,500-7,500 per hectare (Jen, 1984). Naturally regenerated stands require less competition control — between 10 to 12 treatments in the first 10 years, followed by a pre-commercial pruning/thinning treatment after the tenth growing season.

Herbicides have been considered as a much less expensive form of competition control, but are judged by the Taiwan Forestry Bureau to be impractical for two reasons. First, water (the medium of application) is scarce at high elevations. Secondly, it is thought, though not confirmed by research, that the watershed values of the forest would be compromised by herbicide application.

No discussion of forestry in Taiwan would be complete without a tribute to the commercial and cultural value of the many species of bamboo. Moso bamboo, the major commercial species, is managed on a five-year cycle under an uneven-aged system of density regulation. At the end of each growing season, the oldest age class is harvested. This age class contains about 20% of the culms in the stand, which are randomly distributed and identifiable by the unique color-age relationship of the genus. Culm growth of root-sprout origin occurs in the following spring, reestablishing the youngest 20% of the stand. Research is underway on the nutrient dynamics of bamboo, and on the artificial regeneration of bamboo using coppice plantationsilverfurniture (Kao, 1987). A productive stand of Moso bamboo may produce an annual income of more than U.S. $7,400 per hectare (Kao, 1985).

The forest resource plays a major role as both a watershed and water impoundment landscape for low elevation urban centers. Occurrence of precipitation is highly heterogeneous, varying from dry seasons to storms of typhoon intensity. The government of Taiwan is, of course, aware that its forests directly provide the water for the island economy.
and its people. A number of large scale reservoirs and dams have been constructed among the 22 watersheds of Taiwan since the 1950s. Many of these were built in extremely rugged terrain with intense labor forces. Baseline watershed monitoring, initiated in the 1960s, occurs on over a dozen large (100 hectare plus) watershed throughout the island. The effects of silvicultural practices, such as clearcutting and selection cutting, on watershed values are currently being investigated.

At the non-consumable level, the national demand for non-commodity forest resources has increased dramatically with the vigorous national economy and the concomitant increase in the per capita standard of living. Because of increased demand on outdoor recreation, several well known parks, recreational areas, and nature areas have been established for urban dwellers. Among these, the Yangmingshan park, Hsitaou and Chilpchen recreational areas, and the Kenting and Alishan national parks are most prominent, and operate at full capacity during most weekends and holidays. One component of the surge in popularity of noncommodity forest resources is attributable to an increasingly affluent population learning to enjoy and appreciate the beauty of a natural resource setting. A darker component is attributable to the Malithian paradox whereby an increasingly large population undertakes the utilization of an increasingly scarce resource. If the enjoyment of these non-commodity resources follows the pattern of western Europe and North America, use will continue to grow at a nearly exponential rate in the next few decades.

CONSTRAINTS ON FORESTRY

Forest practices in Taiwan are constrained by many factors. The high population on a limited land base, about 36,000 square kilometers, dictates an intensive utilization of available acreage. Intensive agriculture (rice, asparagus and other grain and legume crops), orchards of fruit trees (banana, citrus, pear, apple, vineyard, mango and other scrump-tious native species and varieties), and cash crops (vegetables, mushrooms and the highly profitable betelnut) prioritize the rich, level coastal plains and the lower elevation tablelands and rolling hills. The successful agricultural technology literally pushed forestry practices into the higher and agriculturally inaccessible terrains.

Silvicultural operations at high elevations are often impractical due to the lack of water. This limits the upkeep of facilities for woods workers, constrains the application of fertilizer and perhaps herbicides, and leads to an uncertainty in supply of the basic fire fighting tool of the foresters. Conversely, the amount and intensity of rainfall associated with severe storms and typhoons can wash away plantations, access roads, and even entire mountainsides. Taiwan has a high rate of landslide activity due to its relatively youthful geological age. Timber production at high elevations is usually conducted by clearcutting using skyline logging systems, followed by planting and competition control; whether this intensive timber management predisposes slopes to mass-wasting is a concern of the Taiwan forestry officials. The sheer ruggedness of topography limits operational timber management. Mechanization of forest operations within a forest stand is extremely difficult. Log trucks are modified with water cooled brakes for the steep descent from the logging sites to the mills. Topographic limitations accentuate the disadvantageous aspects of commodity production from the island.

Last and perhaps of greatest significant, sociology comes into play as an operational limitation. As a modern industrialized society, Taiwan is currently experiencing the migration of labor from rural to urban areas. Taiwanese foresters are losing the rural labor pool required to conduct labor-intensive forest operations, particularly those of plantation establishment and competition control in both plantations and natural stands. With respect to balance between commodity and non-commodity resources, the public generally supports efforts by the government to reduce its subsidy of timber management in favor of the watershed and recreational values of the forest.

FORESTRY RESEARCH

Forestry research programs have been conducted in universities and the provincial Taiwan Forestry Research Institute (TFRI) during the past four decades with funding provided from Taiwan's National Science Council, the COA, and private organizations and industries. Two of the three universities in Taiwan offer doctoral programs in forestry, with the National Taiwan University at the forefront in both seniority and academic services.

On the forefront of applied ecology, research is underway at TFRI and at the universities on nutrient cycling in plantation forests (Horng, 1987). Production of Liquidambar formosana Hance and Paulownia taiwaniana Hu and Chang that are resistant to diseases and insects is a major goal of tissue culture research (Yang et al., 1987). Mycorrhizal research focuses on vascicular-arbuscular mycorrhizae in the fast growing hardwood exotic Leucaena (Huang, 1987) and on the mycorrhizal symbiosis of high altitude conifers (Hu, 1987).

During the past decades, both native and exotic species trials have been practices in plantations. Today, the use of natural regeneration is becoming more important, especially in remote areas. Research is underway to improve growth and yield forecasting, and to apply modern technology in the field. Thus the evolution from the historical events to the state-of-the-art has occurred in little more than four decades. These trends are noteworthy because modern Taiwan imports over 90% of its timber and fiber needs.

DISCUSSION AND CONCLUSIONS

The divergence between the operational aspects of timber production and the economic and social limitations upon timber production appear to be increasing in Taiwan. Timber production was fundamental to the establishment of the island economy in the 1990s, but is of decreasing importance. The alternative source of timber for Taiwan is primarily of tropical origin in Indo-Malaysia; all indications are that this source is not immediately renewable. From a global perspective, it is unfortunate that managing temperate forest ecosystems in a constrained manner leads directly to an increased reliance upon tropical ecosystems that are even less able to bear sustainable commodity production.

These divergent demands on the forest ecosystems of Taiwan are by no means resolved. As the population becomes more urban and affluent, the recreational aesthetic and watershed amenities of the forest will become more important. In view of the emphasis placed on sound forestry practices and advanced research, the foundation is in place for farsighted stewardship of the forest ecosystems on the island to meet the growing and diverse demands that characterize the Taiwan forests.

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Forestry on the Island of Taiwan, ROC - The State of the Art


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COMPARISON OF CYCLIC NUCLEOTIDE PHOSPHODIESTERASE IN PHYSARUM FLAVICUM

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ABSTRACT

We have studied both cyclic AMP phosphodiesterase and cyclic GMP phosphodiesterase in the myxomycete Physarum flavicum. The cyclic AMP phosphodiesterase preparations were isolated from both the diploid plasmodial stage of the life cycle and the haploid myxamoebal stage. The plasmodial enzyme was prepared from spent medium (extracellular) and also from purified nuclei. The myxamoebal enzyme was prepared from purified nuclear activity was studied in purified nuclei isolated from the plasmodium. One unusual feature of all the enzymes from the plasmodium is extreme heat stability; they remain catalytically active even after exposure to a boiling water bath for twenty minutes. The myxamoebal enzyme lost all activity after five minutes in a boiling water bath. All four enzyme preparations gave linear product formation with time and all were inhibited by isobutyl-methyl xanthine, a potent competitive inhibitor of cyclic nucleotide phosphodiesterase.

INTRODUCTION

Cyclic 3',5'-adenosine monophosphate (cyclic AMP) has been shown to be of major importance in regulating cellular events in eukaryotic cells. Cyclic 3',5'-guanosine monophosphate (cyclic GMP), although much less understood, is rapidly gaining attention from many researchers. Both cyclic nucleotides have been studied in many eukaryotic and prokaryotic systems (Pastan et al., 1975).

The regulation of the intracellular (and extracellular) levels of these cyclic nucleotides is coordinated by both synthetic enzymes and degradative enzymes. Cyclic AMP is synthesized by adenylyl cyclase and degraded by cyclic AMP phosphodiesterase. Cyclic GMP is synthesized by guanylate cyclase and hydrolyzed by cyclic GMP phosphodiesterase. The work of our laboratory has emphasized the degradative enzymes for both cyclic nucleotides in the myxomycete Physarum flavicum.

Myxomycetes offer a unique model for the study of cellular differentiation and mitotic synchrony (Gray and Alexopoulos, 1968; Aldrich and Daniel, 1982). The life cycle of myxomycetes involves a number of stages that alternate between diploid and haploid structures. The vegetative diploid phase is a macroscopic, single-celled plasmodium. This single cell is multinucleated, with all the nuclei dividing at the same time (mitotic synchrony). Under adverse conditions the plasmodium can differentiate into a dormant sclerotium, which can reform into a plasmodium upon the return of appropriate environmental conditions. A second option available to the plasmodium is the formation of fruiting bodies with the production of haploid spores. These spores can germinate to form the vegetative, single cell haploid phase of the life cycle (myxamoebae and swarm cells). Each of these cells is microscopic and contains one nucleus. These haploid structures can fuse together to form the diploid plasmodium and the life cycle is completed.

Cyclic AMP phosphodiesterase and cyclic GMP phosphodiesterase have been studied in the myxomycete Physarum flavicum in our laboratory (Lynch and Farrell, 1984; Lynch and Farrell, 1985; Lynch and Ross, 1985; and Bean et al., 1986). These studies have been aimed at identifying the location of the intracellular (or extracellular) enzymes and characterizing these proteins. We have shown the existence of cyclic AMP phosphodiesterase in the medium of the plasmodium and in several different intracellular locations, including within the nucleus. A cyclic GMP phosphodiesterase from the medium has also been identified in the plasmodium of P. flavicum. We have recently extended our studies to include cyclic AMP phosphodiesterase from the nucleus of the haploid stage of the life cycle (myxamoebae). This paper will compare data from both cyclic AMP and cyclic GMP phosphodiesterase in P. flavicum. Our work here includes three studies on the plasmodium and one on the myxamoeba. The plasmodial investigations confirm the presence of both a nuclear cyclic AMP and cyclic GMP phosphodiesterase as well as an extracellular cyclic AMP phosphodiesterase isolated from the spent medium. Within the myxamoeba we have studied a nuclear cyclic AMP phosphodiesterase. We believe that this is the first such report of a nuclear cyclic AMP phosphodiesterase in the haploid stage of any myxomycete.

MATERIALS AND METHODS

Both plasmodia and myxamoebae of Physarum flavicum were grown in liquid shake culture and harvested as previously described (Lynch and Farrell, 1985). The organisms were inoculated into two liter flasks containing one liter of semi-defined medium. Normally 3-6 liters of each batch of cells were grown at one time. Both sets of cells were harvested at late log phase, usually about 5-7 days, depending on the inoculum. It should be emphasized that in liquid cultures both myxamoebae and swarm cells are present. Myxamoebae are the predominant cell type. To facilitate usage, these haploid cells will be referred to as myxamoebae.

Three different preparations were used for the measurement of either cyclic AMP or cyclic GMP phosphodiesterase. Crude spent medium from plasmodial cultures was used to determine the activity of extracellular cyclic AMP phosphodiesterase. This medium was collected from the late log cultures described above. After centrifugation at 2,500xg the medium was decanted and saved for cyclic AMP analysis. The cells were washed several times and used for nuclear isolation. Nuclei were isolated according to Henney and Yee (1979) and Bean et al. (1986). The plasmodial nuclear preparations were used for measurements of both cyclic AMP and cyclic GMP phosphodiesterase activity.

Myxamoebae were also collected by centrifugation at 5000xg for seven minutes. They were washed several times in 20 mM Tris HCl (pH 8.0). The cells were homogenized and the nuclei purified by the procedure described above for the plasmodial nuclei. Myxamoebae nuclei were used to measure cyclic AMP phosphodiesterase activity.

Both cyclic AMP and cyclic GMP phosphodiesterase activity were measured by a two-stage anion-exchange resin procedure as described previously (Lynch and Cheung, 1975). The extracellular cyclic AMP phosphodiesterase and the myxamoebae enzyme were assayed at pH 8.0 (Tris HCl). The cyclic AMP and cyclic GMP phosphodiesterase from the nuclei of the plasmodium were assayed at pH 5.5, where they both exhibited maximum activity. Included in the reaction mixture was 5 mM MgCl₂, 0.05 mM CaCl₂, and 2 mM H'-cyclic AMP or H'-cyclic GMP. The concentration of H'-cyclic AMP in the measurements of the myxamoebae phosphodiesterase was 0.1 mM. Radioactive cyclic AMP and cyclic GMP were purchased from Amersham. Unlabelled cyclic nucleotides were obtained from Sigma Chemical Co.
Comparision of Cyclic Nucleotide Phosphodiesterase in Physarum flavicomum

The enzyme reaction was initiated with the addition of sample from one of the preparations described above. Incubation was at 30°C for 10-20 minutes, depending on the sample. The enzyme activity of the heat labile preparation was terminated by placing the tubes in a boiling water bath. The heat stable enzyme was terminated with acid and base as described by Lynch and Farrell (1985). Upon equilibration to 30°C, 0.05 mg of snake venom (Crotalus atrox) was added as a source of 5’ nucleotidase. This step quantitatively converted all ‘H-nucleotides to ‘H-nucleosides and inorganic phosphate. The snake venom reaction was stopped by the addition of 1.0 ml of a 33% slurry of AG1-X2 anion exchange resin (Bio-Rad). The tubes were centrifuged and aliquots of the supernatant fraction, which contained either ‘H-adenosine or ‘H-guanosine, were analyzed for radioactivity in a Packard 300C Liquid Scintillation Counter. When appropriate, enzyme activity was based on protein phosphodiesterase activity cannot accurately be expressed on a protein basis, this activity was expressed as product formed per ml of medium.

RESULTS

One of the characteristics of cyclic nucleotide phosphodiesterase from the plasmodium of P. flavicomum is heat stability. We have found that the enzyme from some intracellular locations is extremely heat stable. Table 1 compares the heat stability of phosphodiesterase from different locations in the plasmodium and from the nucleus of the myxamoeba. Heat stability was determined by placing the protein samples in a boiling water bath for five minutes. At the end of five minutes the samples were returned to 30°C and enzyme activity was determined in both the heated sample and in the unheated control sample. Although the specific activities varied, all the plasmodial samples were heat stable for the time indicated. The nuclear enzyme from the haploid stage of the life cycle was denatured during the heating process.

The previous data showed the results of enzyme activity after exposure to a boiling water bath for five minutes. The next set of experiments was designed to determine if the enzymes could be denatured with a longer boiling time. As can be seen in Table 2, the fractions that showed heat stability in Table 1 also retained heat stability when exposed to a boiling water bath for up to twenty minutes. As would be expected from the results of Table 1, the myxamoeba enzyme lost all activity after five minutes.

Isobutyl-methyl xanthine (IBMX) is generally considered to be a potent competitive inhibitor of cyclic nucleotide phosphodiesterase. Table 3 shows the results of enzyme activity in the presence of various concentrations of IBMX. The extracellular enzyme activity was determined in the presence of only one concentration of IBMX whereas the other samples were measured in the presence of four different IBMX concentrations. All the samples were inhibited by this compound and when used at different concentrations, enzyme inhibition was concentration dependent. Inhibition by IBMX indicates the presence of a cyclic nucleotide phosphodiesterase enzyme.

Another type of experiment that strongly supports the presence of an enzyme is a continuous assay where the amount of product formed is monitored with increasing time. Such a series of experiments is shown in Figure 1. Enzyme activity was measured at each of the time data points shown on the abscissa. At the time intervals indicated, aliquots were removed and the amount of product formed for that time period was determined as described in the Materials and Methods. All four samples showed a linear increase in product formed per time interval.

DISCUSSION

The results presented in this paper compare some of the recent data available for both cyclic AMP phosphodiesterase and cyclic GMP phosphodiesterase in Physarum flavicomum. These enzymes have been shown to be present in various intracellular locations of several stages in the life cycle of this organism.

One unusual feature of the plasmodial enzyme studied here is their extreme heat stability. The heat stability of the extracellular phosphodiesterase was first suggested in 1971 when Murray (Murray et al., 1971) commented on the "unusual stability of the extruded enzyme". Extremely stable extracellular enzymes are understandable in that an organism has very little control over its outside environment. The more resistant an enzyme is to the external environment, the greater ability it would have to degrade any compound that might disrupt the organisms normal regulatory mechanisms.

Why a nuclear enzyme would be heat stable is unknown. One obvious suggestion is that the extracellular enzyme and the nuclear enzyme from the plasmodium are identical or similar in structure and that heat stability is an inherent characteristic of the molecule. Reason suggests that the two proteins should be genetically distinct in that any regulatory mechanisms that activate (or inhibit) a nuclear enzyme would presumably be different from those that regulate an enzyme that is released to the outside of the cell.
The regulatory role of the plasmodial cyclic AMP and cyclic GMP phosphodiesterase in the nucleus is unknown at this time. Adenylate cyclase, the enzyme responsible for the synthesis of cyclic AMP, has also been shown to be present in the nucleus of Physarum (Atmar et al., 1976). In general it has been noted that in cells growing in culture, factors that decrease cyclic AMP tend to stimulate cell proliferation whereas those that increase cyclic AMP levels tend to inhibit growth rate (Pasan et al., 1975). Knowing the multi-nucleated condition of the plasmodium and the naturally occurring mitotic synchrony, it will be interesting to see if cyclic nucleotides play a role in maintaining this synchronous mitosis.

The nuclear cyclic AMP phosphodiesterase from the myxamoeba does seem to be a separate protein from its counterpart in the plasmodium. This is suggested by the differences in heat stability, with the myxamoeba enzyme being heat labile while that from the plasmodium is heat stable. The myxamoeba are single cells containing one nucleus. Even though there is no mitotic synchrony in these cells, it is still possible that cyclic nucleotides may play a role in cell division in the haploid stage of the life cycle.

A question that remains to be answered is whether the cyclic AMP and the cyclic GMP phosphodiesterase from the plasmodial nucleus are the same protein or are separate, distinct proteins. Our preliminary data (not shown in this paper) suggest that they may indeed be one and the same protein. This question cannot be answered with certainty however until the enzymes are purified to homogeneity.

LITERATURE CITED


Comparison of Cyclic Nucleotide Phosphodiesterase in *Physarum flavicomum*


ANALYSIS OF WILDFIRE OCCURRENCE IN SOUTHEASTERN ARKANSAS, 1984-1987

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University of Arkansas at Monticello
Monticello, AR 71655

ABSTRACT

Wildfire statistics for Arkansas Forestry Commission District I in southeastern Arkansas were analyzed for the period 1984 through 1987. A mean of 313 fires and 1103 hectares burned annually during the study period. Most (87%) of the land burned was forested. The greatest number (90%) of wildfires occurred when fire danger was moderate to high. Most fires were started (90%) and detected (51%) by local residents. Arson was responsible for the majority of fires (68%) and hectares burned (65%). A disproportionately high number (43%) of the incendiary fires occurred in Ashley County. Mean fire size was smaller in this county. Fire suppression professionals attribute this to increased surveillance and suppression efforts in the county as compared with other counties. Many more fires occurred in 1987 than in previous years. On forest-industry land more fires occurred in 1987 than in previous years (85% vs. 42%). Also, for all lands, more fires were of incendiary origin in 1987 than in previous years (78% vs. 60%). The authors provide evidence that the change in fire pattern in 1987 was due in part to a drastic change in administration of hunting privileges by a major forest industry in the area.

INTRODUCTION

Despite the fear or respect with which most people treat fire, considerable loss of property, and occasionally human life, occurs annually from forest wildfires. In spite of the wildfire awareness crusades championed by Smokey Bear, arson continues to be the largest single cause of wildfires in the South (U.S. Department Agriculture, 1980). Unfortunately, well-meaning individuals continue to set forest and open-land fires due to a misunderstanding of fire's ecological effects or an overestimation of their ability to control fire. Many of these fires escape control and culminate in wildfires.

The Arkansas Forestry Commission (AFC) is the principal organization charged with wildfire suppression in the state. For administrative purposes the AFC is organized into districts of about 0.7 million hectares each that typically include four to seven counties.

The 1987 spring fire season (January through June) in southeastern Arkansas was typical. However, the fall fire season was an anomaly, compared to the three previous years. Beginning with the first weekend in September, the number of wildfires increased sharply and continued for several months. These fires were concentrated on forest-industry lands and were of incendiary origin (arson). This research was undertaken to determine the typical pattern of wildfire occurrence in southeastern Arkansas and to investigate causes of the anomaly that occurred in 1987.

METHODS

A data set for AFC District I was developed from Individual Fire Reports for 1984-1987 (AFC Form 2410.1). For each year, 20% of the Individual Fire Reports were randomly sampled. District I includes Ashley, Chicot, Cleveland, Desha, Drew, Jefferson and Lincoln counties in southeastern Arkansas (Figure 1). Chicot and Desha counties include mostly Delta agricultural land and fire occurrence in these counties is extremely low. The random sample did not include fires in either of these two counties.

Information recorded for each fire included: year, county, type of fire (forest, non-forest or a combination), day of the year, statistical cause (e.g. arson — wildfires wilfully set by anyone to burn vegetation or property not owned or controlled by the person, and without consent of the owner or the owner's agent; debris burning — wildfires spreading from clearing land, burning trash, range, stubble, logging debris, or other prescribed burning), who discovered the fire (aerial, tower, or ground surveillance by AFC, or general public), how the fire was extinguished (suppression, burn out or rain out) and fire-danger class-day. Fire-danger class-day is a measure of the total wildfire danger anticipated for an area. It is calculated based on anticipated fire behavior. Class I denotes low fire-danger, while Class 5 denotes extreme fire-danger. Arkansas uses a modified form of the 1972 National Forest-Danger Rating System (Deeming et al., 1972). A second data set was compiled which contained the year, day of the year, month, and class-day for each day of the four-year period. Finally, data on number of fires by statistical cause and hectares burned for Arkansas and each county in District I were obtained from the Annual Fire Reports—Classification and Size Statistics, published by the Arkansas Forestry Commission.

The analysis of fire data was done with a standard statistical package (Morsis, 1988) using a multiple dimension frequency analysis.

Figure 1. Seven-county study area in southeast Arkansas.
Analysis of Wildfire Occurrence in Southeastern Arkansas, 1984-1987

Table 1. Number and size of forest/non-forest wildfires in Arkansas Forestry Commission District I (southeastern Arkansas), 1984-1987.

<table>
<thead>
<tr>
<th>Year</th>
<th>1984</th>
<th>1985</th>
<th>1986</th>
<th>1987</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Wildfires (N)</td>
<td>533</td>
<td>313</td>
<td>376</td>
<td>322</td>
<td>376</td>
</tr>
<tr>
<td>Forest Fires (N)</td>
<td>462</td>
<td>248</td>
<td>276</td>
<td>287</td>
<td>278</td>
</tr>
<tr>
<td>Non-Forest Fires (N)</td>
<td>71</td>
<td>65</td>
<td>86</td>
<td>35</td>
<td>58</td>
</tr>
<tr>
<td>Mixed Forest &amp; Non-Forest Fires (N)</td>
<td>76</td>
<td>62</td>
<td>90</td>
<td>67</td>
<td>80</td>
</tr>
<tr>
<td>Total Area Burned (Ha)</td>
<td>1,720</td>
<td>1,103</td>
<td>2,714</td>
<td>1,448</td>
<td>1,720</td>
</tr>
<tr>
<td>Forest Area Burned (Ha)</td>
<td>695</td>
<td>464</td>
<td>1,314</td>
<td>1,424</td>
<td>1,079</td>
</tr>
<tr>
<td>Non-Forest Area Burned (Ha)</td>
<td>109</td>
<td>221</td>
<td>134</td>
<td>126</td>
<td>138</td>
</tr>
<tr>
<td>Forest Area Burned per Fire (Ha)</td>
<td>14.5</td>
<td>16.0</td>
<td>14.5</td>
<td>13.2</td>
<td>14.0</td>
</tr>
<tr>
<td>Non-Forest Area Burned per Fire (Ha)</td>
<td>3.5</td>
<td>3.4</td>
<td>3.3</td>
<td>3.1</td>
<td>3.1</td>
</tr>
<tr>
<td>Average Fire Size (Ha)</td>
<td>31.9</td>
<td>27.8</td>
<td>32.2</td>
<td>31.0</td>
<td>31.2</td>
</tr>
</tbody>
</table>

Source: Arkansas Forestry Commission, Annual Fire Reports

Table 2. Number and percentage of wildfires by the two leading causes and area burned for Arkansas and for Arkansas Forestry Commission District I (southeastern Arkansas), 1984-1987.

<table>
<thead>
<tr>
<th>Year</th>
<th>1984</th>
<th>1985</th>
<th>1986</th>
<th>1987</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Totes</td>
<td>1,650</td>
<td>1,111</td>
<td>783</td>
<td>2,170</td>
<td>2,040</td>
</tr>
<tr>
<td>Cause</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arson</td>
<td>39</td>
<td>60</td>
<td>43</td>
<td>53</td>
<td>55.2</td>
</tr>
<tr>
<td>Debris burning</td>
<td>31</td>
<td>22</td>
<td>30</td>
<td>21</td>
<td>26.7</td>
</tr>
<tr>
<td>Dist. Total</td>
<td>123</td>
<td>450</td>
<td>274</td>
<td>804</td>
<td>332</td>
</tr>
</tbody>
</table>

Source: Arkansas Forestry Commission, Annual Fire Reports

RESULTS

The completed data set included 252 fires occurring over the four-year study period. Table 1 shows the number and size of wildfires by type. The number of fires and hectares burned increased each year, with a mean of 313 fires and 1,103 hectares per year over the 4-year period. Of the total hectares burned, 87% were forested. Each fire burned about 3.1 forested hectares and 0.4 non-forested hectare.

Table 2 shows the two major causes of wildfires by year for all of Arkansas and for District I. As expected from historical records (U.S. Department Agriculture, 1980), arson remained the leading cause of wildfires, with fire escapes from debris burning distant second. Notably, the percentage of fires caused by arsonists increased with time, both state-wide and in southeastern Arkansas. However, there was no trend for percentage of hectares burned by arson-caused fires. Wildfires caused by debris burning tended to decrease with time, both state-wide and in District I for percentage of fires and for percentage of hectares burned. Mean percentage of wildfires caused by arsonists was much higher in southeastern Arkansas than the state-wide average (68% vs. 48%). Although the trend was similar for hectares burned, the difference was not as great (55% vs. 59%). The reverse pattern was true for mean number of fires caused by debris burning, with southeastern Arkansas lower than the state-wide mean (19% vs. 26%). Mean percentage of hectares burned by wildfires started by debris burning was similar for Arkansas and District I. For southeastern Arkansas, arson and debris burning combined for 87% of the fires started and 83% of the hectares burned. The remaining fires were started by: equipment 2.8%, children 2.1%, railroads 1.7%, campfires 0.8%, lightning 0.8%, smokers 0.5%, and other miscellaneous causes 4.6%.

The AFC’s aerial patrols discovered 28% of the fires, observers in towers discovered 8% and AFC ground patrols 12%, while local residents reported 51%. Almost 70% of the fires on non-industry private land were discovered by local residents. However, fires on forest-industry land were more often (53%) discovered by active patrols. Incendiy fires were more likely (53%) to be discovered by local residents than by active patrols. Active fire suppression extinguished 97% of the fires, while 3% burned out by themselves. Fires were as likely to occur in spring (49%) as in fall (51%).

The owner of the land on which the fire occurred was responsible for starting 14% of the wildfires. Local residents accounted for 59%, non-residents of the area accounted for 49% and “unidentified agents” started 18% of the wildfires. Only three groups were responsible for arson fires: local residents started 82%, non-residents started 12% and unknown persons caused the remaining 6%.

On days when fires occurred, 7% were ignited on Class 1 fire-danger days, 48% on Class 2, 42% on Class 3, 2% on Class 4 and 1% on Class 5 days. These percentages for fire-days by class-day did not differ over the study period.

Ashley County has historically been an area with a high incidence of incendiary fires; this trend continues. Of the total arson fires recorded for District I over the 4-year period, 43% were started by local residents of Ashley County. Arson-starts by local residents for the other counties were: Jefferson 15%, Drew 14%, Cleveland 8%, and Lincoln 2%. Ashley County consistently reports a disproportionately large number of all District I fires (43%) and District arson-caused fires (34%) (Table 3). However, in Ashley County, the percentage of hectares burned by...
incendiary fires has been less than the percentage of incendiary fires by number. In other counties in the District these percentages are usually reversed (Table 3). These statistics may be attributed to the detection and suppression activities of AFC and forest-industry fire fighters, which are concentrated in Ashley County. Emphasis on detection and suppression in areas of high wildfire-incidence tends to keep fire size smaller by reducing total suppression time (Deeming et al., 1985).

For District I, fire-danger was significantly higher statistically in 1987 than in the other three years of the study. For 1984-1986, 41% of the days were Class 1, and 58% were Class 2 or 3 days. However, for 1987, 28% were Class 1 and 70% were Class 2 or 3 days. Fire-danger did not by itself, however, explain the anomalous fall fire-season of 1987. More fires occurred on forest-industry land (65%) during 1987 than in the previous three years (42%). In addition, proportionately more incendiary fires in 1987 (78%) than other years (60%). Also, in 1987, 91% of the fires on forest-industry land originated by arson, with local residents responsible for 90%. The majority (65%) of 1987 fires on non-industry private lands were also the product of arsonists, with 92% started by local residents.

**DISCUSSION**

The increasing number of fires over time is a cause for concern to fire suppression organizations and to forest landowners. Industrial forestland managers, facing the additional threat of arson, have just cause to be anxious.

Results of a study of national wildfire statistics from 1973 to 1978 (U.S. Department Agriculture, 1980) revealed that 39% of the wildfires and 55% of the hectares burned in the southern region were of incendiary origin, 26% of the fires and 20% of the hectares burned were started by debris burning. Arkansas and southeastern Arkansas are almost 10 and 20 percentage points, respectively, above the 5-year regional mean. Although explanations for these phenomena are many, several dominate. First, southeastern Arkansas has a mostly rural population that traditionally uses fire for land-management purposes, especially burning to manage unwanted vegetation and fuels that accumulate in the vast pine forests of southern Arkansas. Second, southeastern Arkansas has a climate that produces both an abundance of fuels and the seasonal weather patterns that carry wildfires through these cured fuels (Schroeder and Buck, 1970). Third, there is a tendency for local residents to deliberately set fires on the lands of another. The forested areas of southeastern Arkansas, especially in Ashley County, have a lengthy history of incendiary fires. Fortunately, the wildfires in Ashley County are kept "smaller" due to the surveillance and suppression efforts concentrated there.

There are several possible explanations of the anomalous 1987 fall fire season. The higher occurrence of Class 2 and 3 days played a part in the spread of fires once started. The class-day fire-danger classification scheme takes into account weather and fuel-flammability conditions. While there was an increase in fire-danger during 1987, the increase alone did not totally explain the disproportionate rise in incendiary, nor the fact that the majority of the increase in fire numbers was on forest industry land.

Concurrent with the beginning of the increase in incendiary fires was the beginning of small-game hunting season on September 12 and deer-hunting season on October 1 in southeastern Arkansas. The 1987 hunting season also marked the beginning of a drastically different policy concerning hunting on forest-industry lands in the study area. Prior to 1987, public access to most forest-industry lands in the seven-county area was unrestricted. Access was on a first-come basis, with some local hunting clubs claiming "rights" to certain areas by tradition. However, in 1987, the principal forest-industry landowner in the areas leased all hunting privileges on about 200 thousand hectares to hunting clubs. This precluded unrestricted and free access by the general public and denied access to many individuals who had hunted on these lands all of their lives. Most of these individuals had viewed the forest-industry lands as quasi-public in nature. Thus, we feel that the decision to lease land for hunting was the single most important factor in the high incidence of incendiary fires on forest-industry lands in 1987.

Studies of arsonists have indicated that people starting fires generally come from a rural background, are less well socially integrated and tend to have less formal education than the norm (Bertrand et al., 1970; Bertrand and Baird, 1975; Bradshaw and Huff, 1985). Additionally, results reported by Doolittle and Lightsey (1979) showed that the great majority of fire starters on the lands of another for traditional land-management reasons is at least tolerated if not often approved of in many cases by local populations. However, acts of pure vandalism are seldom condoned. Social protection of fire starters and the general perception that industry or public lands belong to everyone add to the problem of curtailing such behavior.

Doolittle and Lightsey (1979) emphasized that local perception of public and industry lands is strongly shaped by the company or agency's representative with local responsibility. If the local representative is viewed as a policeman from outside, rather than as a community member, there is a high likelihood of multiple land-management problems.

Based on results of a survey of fire industries in the southeastern U.S., Kluender (1978) found that 91% of the responding companies leased land for hunting and/or other privileges. Public response to these leasing programs was highly favorable (95%). Additionally, it was concluded in the same study that promoting a feeling of surrogate ownership and the use of local residents to actively help in protecting industry land was desirable and achievable. Such a high degree of cooperation was generally realized by preferential treatment of locals in hunting-lease assignments, firewood permits and educational endeavors.

**CONCLUSIONS**

Organized wildfire detection in high risk areas and during high risk periods coupled with rapid reponse by trained fire suppression professionals are important factors in reducing the total acreage burned by wildfires. While the anomalous fall fire season of 1987 did incinerate valuable timber and open land, it was not the catastrophe that could have occurred had active surveillance and suppression not been practiced during the fall fire season. Finally, successful local administration of policy changes by large landowners requires a sustained flow of information in addition to well nurtured interpersonal relationships between landowner representatives and local residents.

**ACKNOWLEDGEMENTS**

This paper was approved for publication by the Director, Arkansas Agricultural Experiment Station. Doug Grimmett, AFC District Forester, provided the raw data for District I.

**LITERATURE CITED**


Analysis of Wildfire Occurrence in Southeastern Arkansas, 1984-1987


FACTORs AFFECTING ANNUAL DEER HARVEST IN ARKANSAS

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ABSTRACT

An understanding of general forces affecting annual harvest is essential to the management of white-tailed deer (Odocoileus virginianus). A predictive model based on such factors would be valuable to managers. The relationship between 27 different variables and annual, legal deer harvest in Arkansas was evaluated for 1957-1986. Variables most affecting harvest were soybean acreage, hay acreage, number of days in the deer season, rain during the deer season, and total state timber production, total state pulpwood production, and deer harvest 2 years prior. Because significant autocorrelation and heteroscedasticity were present in the variables, log-linear, first differencing and non-linear quasi-Newton regression methods were used in addition to ordinary least squares. First differencing removed autocorrelation and heteroscedasticity, but fit was not acceptable ($R^2 = 0.710$). Non-linear estimation of first differenced log transformed variables provided an acceptably high $R^2 (0.896)$ with high significance of the individual parameter estimators. Factors associated with habitat quality 2 years prior most affected present-year deer harvest.

INTRODUCTION

Numerous attempts have been made to identify those factors most closely associated with white-tailed deer (Odocoileus virginianus) harvest (Fobes, 1945; Mechler, 1970; Hansen et al., 1986). The ability to project harvest would enable managers to make better decisions regarding season parameters, and harvest and user regulations. Policy developed from incorrectly formulated models, however, can lead to disastrous consequences. Estimating legal deer harvest for policy reasons, thus, requires a proper knowledge and appreciation of the factors that influence annual harvest and the appropriate statistical tools to interpret them.

Many of the factors potentially affecting annual deer harvest, such as annual license sales, are classified as time-series variables. Present levels of time-series variables are at least partially dependent on antecedent levels. When this type of variable is used with ordinary least squares regression (OLS) modeling techniques, the error term may display autocorrelation and/or heteroscedasticity. Autocorrelation exists when the error term in one period is not independent of its value in other periods. Heteroscedasticity exists if there is unequal variance over time. The presence of either of these problems violates the fundamental assumptions of OLS regression (Neter and Wasserman, 1974). In addition, OLS methodology requires that the analyst specify the functional form of the estimated equation. There are, of course, no biological guidelines for specifying the relationships among variables potentially affecting deer harvest.

Two errors commonly derive from improper methodology in developing statistical models. First, variables are often included solely from their ability to reduce the unexplained variance of the dependent variable (Lovell, 1983). A second error is caused when the assumptions of OLS regression are not satisfied. This results in the estimators of the parameters not being best linear unbiased estimates of their true values. Therefore, the models themselves and structural inferences drawn from them may not be valid.

The objectives of this study were to (1) evaluate methods of modeling annual deer harvest using data commonly available to state wildlife agencies, and (2) use the most appropriate modeling technique to determine what factors affect annual deer harvest in Arkansas.

METHODS

Twenty-seven variables for the period of 1957 through 1983 were examined for inclusion in a reliable structural model of annual, legal deer harvest. Data were obtained from the Arkansas Game and Fish Commission, the Arkansas Cooperative Extension Service's Crop Reporting Service, the National Oceanographic and Atmospheric Administration, and the Arkansas Forestry Commission. For each year, variables examined were annual legal deer harvest, sales of resident hunting licenses and dog licenses, number of days in the modern weapon, archery, crossbow and muzzleloader seasons, number of seasons per year for modern weapons, bag limits, total state production of timber and pulpwood, acreages of corn, soybeans, oats, hay, sorgum, wheat and rice, number of farms, and November rainfall in the Coastal Plain region (where most of the state’s deer harvest is taken). Each time-series variable was also lagged 1 and 2 years.

Variables that were used in the modeling effort were chosen by a three step process. First, variables that showed a high correlation ($r > 0.75$) with the dependent variable were noted. Second, for these variables, only if there was a strong visual relationship between the dependent and independent variables, was the variable designated for possible inclusion in the modeling effort. Final selection of variables for inclusion was made with the stepwise regression process. A parameter significance of $P < 0.1$ was required for final inclusion in the model (Wilkinson, 1986). First-differencing (Neter and Wasserman, 1974) and logarithmic transformations were performed on all variables.

Five separate models were analyzed and the residuals checked for compliance with the underlying assumptions of OLS regression (Steel and Torrie, 1960). The five models were 1) standard OLS regression, 2) OLS regression of first-differenced data, 3) OLS regression of log-linear transformed data, 4) non-linear quasi-Newton regression (Wilkinson, 1986) of untransformed variables and 5) log-linear estimation of first-differenced and log-transformed data using quasi-Newton regression techniques (Wilkinson, 1986). All analyses were performed using SYSTAT (Wilkinson, 1986). Statistical significance was accepted at the $P < 0.05$ probability level.

Elasticities (Pindyck and Rubinfeld, 1981) were computed for each variable included in the models. Elasticity is a ratio of responsiveness.
Factors Affecting Annual Deer Harvest in Arkansas

and is computed by dividing the percent change in the dependent variable by the associated percentage change in an independent variable. An elasticity value of 2.0 would indicate that for every 1% change in the independent variable a 2% change would occur in the dependent variable. If an elasticity value is less than one, the relationship is said to be inelastic. A value of one is said to be unitary elasticity, and a value greater than one is termed elastic.

RESULTS AND DISCUSSION

Variables chosen were soybean acreage (current-year and 2 years prior), current-year hay acreage, state total timber production (2 years prior), state pulpwood production (2 years prior), deer harvest (2 years prior), days in modern weapon seasons and rain during the month of November (Table 1).

The error terms associated with three of the models resulted in violations of OLS regression assumptions. OLS regression of untransformed variables produced a model with a high $R^2$ (0.93) but autocorrelation and heteroscedasticity were present. OLS regression of first-differenced variables produced a model free of autocorrelation and heteroscedasticity but with a relatively low $R^2$ value (0.71). The log-linear OLS regression ($R^2$ = 0.93) model resulted in heteroscedasticity in the residuals.

The error terms for two models (conformed to the assumptions of OLS regression. The non-linear estimation process using untransformed data, free of the assumptions shackling OLS regression, provided the best fit ($R^2 = 0.994$) and high “t” values of the parameter estimators.

Further, non-linear regression provided a multidimensional response surface conceptually compatible with a dynamic process such as wildlife harvest over time. However, untransformed data used in this method was not free of time-related bias. Sequential observations of independent variables had a high multiple correlation coefficient but could have been related to a third unidentified variable proxied by time. Without addressing this problem, increasingly distorted projections would occur.

The $R^2$ (0.896) for the differed, log-transformed variable set modeled with the quasi-Newton method was lower than for the non-linear estimation of untransformed variables. However, the transformed data set had several advantages. First, since the variables were stripped of long-term time trends before modeling, their true relationship to each other was modeled. Second, auto-or serial correlation was removed from the series before modeling. Even though lagged variables were present, their selection for the model was not based on their ability to reduce autocorrelation. Rather, each variable stood alone in explaining variation of the dependent term. Finally, the quasi-Newton method of regression converges on the parameter estimates through an iterative process which can continue to the degree of precision desired. Therefore, parameter estimates generally had a lower standard error associated with them than with other methods. Only one variable was not significant at the 0.05 level, and only two were not significant at the 0.01 level (Table 1).

We hypothesize that the independent variables included in the models may be grouped as 2 sets of factors: those affecting hunt intensity and those influencing deer population density. Variables that could affect population density were timber production, pulpwood production, soybean acreage and deer harvest (all two years prior). Factors possibly related to hunt intensity were those for the current year: soybean acreage, hay acreage, days in modern weapon seasons and rainfall during November.

With the exception of current-year soybean acreage, all factors were found to be inelastic. That is, current-year deer harvest was not very responsive to changes in the independent variables (Table 1). Factors associated with population density two years prior had a stronger (2 to 3 times) influence on deer harvest than factors associated with hunt intensity but were only slightly inelastic with respect to harvest.

There are many possible explanations for how each variable related to population density could affect annual deer harvest. Timber production data used in this study includes clear cutting, which connotes severe stand disturbances and site preparation practices. These activities may disrupt forage production and diminish cover for a period of 1 to 2 years. In contrast, pulpwood production includes operations that often remove mid-story and create canopy openings without site preparation, thereby providing increased browse production. Thus, the difference in signs between pulpwood production and total timber production may reflect differences in animal use of harvested areas or alternatively, the ability of hunters to harvest deer. Soybean production two years prior could have provided forage during late spring and

<table>
<thead>
<tr>
<th>Variables</th>
<th>Units</th>
<th>Elasticity</th>
<th>Coefficients</th>
<th>T-value</th>
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</thead>
<tbody>
<tr>
<td><strong>Constant</strong></td>
<td></td>
<td>-0.311</td>
<td>-2.549***</td>
<td></td>
</tr>
<tr>
<td><strong>Present-year</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soybean acreage</td>
<td>Hectares x 1000000</td>
<td>-1.21</td>
<td>-1.209</td>
<td>-3.489***</td>
</tr>
<tr>
<td>Hay acreage</td>
<td>Hectares x 1000000</td>
<td>+0.31</td>
<td>0.307</td>
<td>1.412*</td>
</tr>
<tr>
<td>Seasons length, modern weapons</td>
<td>Days</td>
<td>+0.35</td>
<td>0.354</td>
<td>2.058**</td>
</tr>
<tr>
<td>November rainfall</td>
<td>Cm.</td>
<td>+0.15</td>
<td>0.150</td>
<td>3.125***</td>
</tr>
<tr>
<td><strong>Lagged 2 years</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soybean acreage</td>
<td>Hectares x 1000000</td>
<td>+0.74</td>
<td>0.740</td>
<td>3.045***</td>
</tr>
<tr>
<td>Timber production</td>
<td>Meters x 1000</td>
<td>-0.85</td>
<td>-0.845</td>
<td>-2.118***</td>
</tr>
<tr>
<td>Pulp production</td>
<td>Meters x 1000</td>
<td>+0.99</td>
<td>0.988</td>
<td>2.498***</td>
</tr>
<tr>
<td>Deer harvest</td>
<td>Animals</td>
<td>-0.46</td>
<td>-0.462</td>
<td>-3.787***</td>
</tr>
</tbody>
</table>

* $P < 0.10$.  
** $P < 0.05$.  
*** $P < 0.01$. 

Table I. Results of log-linear estimation of annual deer harvest in Arkansas from 1956-1986 using Quasi-Newton non-linear regression with first-differenced and logged data.
early summer, and beans prior to winter. Thus, a healthy herd two years previous would provide many of the animals that would be harvested in the current year.

The low elasticities for the variables we feel affected hunt intensity, such as modern weapon season length, suggest that these factors had minimal direct effect on deer harvest. The low responsiveness of deer harvest to season length is important to policy decisions. For example, our analysis shows that increasing the hunting season from 30 to 35 days (a 16.7% increase) would result in only a 5.8% increase in deer harvest. Thus, season length could be increased with the expectation that deer kill would not rise proportionately.

There are also numerous explanations for how variables related to hunt intensity could affect annual deer harvest. Of all the variables, current-year soybean acreage had the strongest statistical relationship to deer harvest. The negative elasticity of soybean acreage could be a result of soybeans typically being produced in large fields unsuitable for hunting. Conversely, hay fields in Arkansas are usually much smaller than soybean fields and often provide forage and cover during hunting season. Thus, hay acreage could positively affect harvest. Rainfall may reduce hunter numbers and deer harvest (Curtis 1972; Mechler 1970), but in this study total rainfall during the hunting season had a slightly positive effect on harvest.

CONCLUSIONS

Deer harvests can be projected using data commonly available to state wildlife agencies. However, for best results data must be stripped of their time-dependency before the modeling process. Quasi-Newton nonlinear regression, using first-differenced, logged data, was the most appropriate modeling procedure. Some variables, particularly those related to habitat or previous harvests, may affect deer harvest in subsequent time periods. Therefore, variables should be examined prior to modeling for significant time lags, and so that autocorrelation can be removed.

Based on results of this study, factors associated with habitat quality two years prior to harvest were the most important for determining present-year deer harvest. Only one hunting season factor, days in modern weapon seasons, was important. Many other variables that could affect annual deer harvest, however, were not examined. For example, off-road vehicle use or sales, and sex-age ratios of earlier deer harvests could affect harvest, but these data were not available. It may also be important when modeling deer harvest to account for differences in variables among physiographic regions. Definitive biological cause-and-effect relationships are more difficult to develop than a valid statistical model. While the modeling process we utilized insures statistical validity, adequate explanation of model structure is more difficult. One factor that makes interpreting the model results more difficult is that the data we used was aggregated at the state level. Accordingly, additional research on a regional level is required.

LITERATURE CITED


ARKANSAS' TIMBER RESOURCE: YESTERDAY, TODAY AND TOMORROW

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ABSTRACT

Demand for forest products continues to rise. Arkansas provides about 4% of the U.S. total forest production and about 12% of the south central region production. Questions exist about the ability of current forest resources to completely meet anticipated future demand. In 1985, the U.S. Forest Service and the Arkansas Timber Study Committee began to analyze the existing forest base to determine whether future demand could be met from the current forest, or if not, what management changes were needed to help meet future demand. In 1985, Arkansas forests covered approximately 48% of the total land area of the state. However, the forest land base has changed drastically over the last 20 years. Projections show that changes in forest acreage, ownership, and management types will continue for the next 40 years. Greatest changes in land ownership will occur in the nonindustrial private forest (NIPF) landowner sector. Forest industry lands will show the greatest changes in timber type. Public forest ownerships will continue to be a significant part of the state’s total resource base, but will not undergo the significant changes of other sectors. This paper discusses these trends and the reasons for changes that are occurring.

INTRODUCTION

Total U.S. aggregate demand for forest products is a function of population and the health of the economy. Long-term U.S. forest products consumption correlates highly with the traditional economic growth estimators. These general economic trends form the basis of forecasting long-term demand. Short-term market place fluctuations are generally not considered in long-term projections.

Long-term economic indicators suggest that demand for forest products will continue to rise steadily for the next half century according to the U.S. Department of Agriculture, Forest Service (U.S.D.A., 1987). In 1985, the Forest Service, began an in-depth evaluation of the ability of the nation’s forests to meet forest products demand in the near and long term future. Because of the South’s large forest acreage and fast timber growth rates the southern region was the focal point of the study.

The head of the state forestry agency in each of the southern states was asked to appoint and chair a broad-based committee to provide information for the U.S. Forest Service’s southside study and to simultaneously assess the forests of the individual states. This paper is a report of the Arkansas Timber Study Committee’s analysis of the past and present forests of Arkansas and its projections concerning the future forest.

METHODS

The Arkansas Timber Study Committee consisted of representatives of forest industry, private non-industrial forest landowners, forestry consultants, the Arkansas Forestry Commission and forest research specialists. Committee members were appointed by and served under the leadership of the State Forester. Because of previous forest resource assessment experience, researchers from the Department of Forest Resources, University of Arkansas at Monticello, were selected to act as principal investigators in the study.

The study was divided into several phases. The initial phase was an assessment of the trends in forest acreage and management intentions by ownership class in the state. The first step was to compile resource data from the last U.S. Forest Survey of Arkansas (Quick and Hedlund, 1979a,b,c,d; van Hees, 1980), the Midcycle Survey (Beltz et al., 1987), a U.S. Forest Service special report (U.S.D.A., 1987), and other information from the Arkansas Forestry Commission (unpublished data, Arkansas Forestry Commission, 1986). Additionally, to validate the analysis, 50 forest managers in the state were surveyed regarding their personal and/or company’s plans for changes in the future. The summary provided both qualitative and quantitative information regarding current trends in forest production, anticipated future production changes, and the effect of differing management strategies on their lands.

General management implications for Arkansas’ total forest base were developed based on the committee’s assessment and the survey results. The survey and initial assessment were completed by late 1986. In the second phase projections of forest acres by management type and ownership class were formulated. These projections were made based on long-term and more recent trends and upon the survey responses.

Third, the projections of future acreage and management practices which were developed in the first two phases of the study were used to estimate future timber production for the state. This projection was compared with that developed by the U.S. Forest Service (U.S.D.A., 1987).

Differences in projections made by the Forest Service and by the Arkansas Timber Study Committee were noted and reconciled where possible. In some cases, the Arkansas Timber Study Committee’s projections were accepted as being the most likely future scenario because they were based on more specific data and better knowledge of unique conditions.

Where the Arkansas Timber Study Committee projections and the U.S. Forest Service projections were in close accord the U.S. Forest Service is cited as the original source. Where substantial differences were apparent, the projections of the Arkansas Timber Study Committee were accepted. Findings of other studies are also reported here to complete the present and future picture of the forest resource of the state.

STUDY RESULTS

THE FOREST BASE AND PRODUCTION

In 1985, Arkansas forests covered approximately 48% of the total land area of the state (U.S.D.A., 1987). Of the total land base, 50% was in commercial forest and 29% was in row crops. Other land uses, such as urban areas, rights of way, water, and open land accounted for about 19% of the surface area. Arkansas forests were predominantly hardwood (54.2%). Natural or planted pines and mixed pine-hardwoods...
accounted for 27.4% and 18.3% respectively (U.S.D.A., 1987).
Production from Arkansas' forests has increased over time. Total production in 1965 was slightly less than 500,000 MCF (thousand cubic feet) and in 1985 was 542,208 MCF, an 8% increase. Production dips occurred in 1974-1976 (over 20%) and 1982-1984 (about 10%) and reflected dips in total U.S. lumber demand (Kluender et al., 1988). Traditionally, Arkansas has provided slightly over 4% of the total U.S. production and over 12% of the south-central region's production (Kluender et al., 1988).
Roundwood products had a combined stumpage value of about $237.0 million in 1985. Production from private forest industry lands accounted for $119.4 million or 50% of the total. Another 40% ($95.0 million) came from stumpage payments to private non-industrial forest landowners and 10% ($22.6 million) was for timber harvested from public ownerships (Kluender et al., 1987).

### Table 1. Total Arkansas by management type, 1952 to 2030, in 1000's of acres.

<table>
<thead>
<tr>
<th>Year</th>
<th>Plantations</th>
<th>Natural</th>
<th>Mixed Pine</th>
<th>Hardwood</th>
</tr>
</thead>
<tbody>
<tr>
<td>1952</td>
<td>55</td>
<td>4481</td>
<td>2181</td>
<td>4410</td>
</tr>
<tr>
<td>1962</td>
<td>161</td>
<td>6909</td>
<td>2667</td>
<td>8351</td>
</tr>
<tr>
<td>1970</td>
<td>236</td>
<td>4180</td>
<td>2870</td>
<td>7779</td>
</tr>
<tr>
<td>1977</td>
<td>413</td>
<td>3802</td>
<td>2956</td>
<td>6991</td>
</tr>
<tr>
<td>1985</td>
<td>990</td>
<td>3377</td>
<td>2926</td>
<td>5970</td>
</tr>
<tr>
<td>1990</td>
<td>1486</td>
<td>3026</td>
<td>2743</td>
<td>5511</td>
</tr>
<tr>
<td>2000</td>
<td>2558</td>
<td>2296</td>
<td>2399</td>
<td>5076</td>
</tr>
<tr>
<td>2010</td>
<td>3027</td>
<td>2197</td>
<td>2132</td>
<td>4555</td>
</tr>
<tr>
<td>2020</td>
<td>3237</td>
<td>2158</td>
<td>2004</td>
<td>4697</td>
</tr>
<tr>
<td>2030</td>
<td>3348</td>
<td>2109</td>
<td>2001</td>
<td>4654</td>
</tr>
</tbody>
</table>


### THE CHANGING FOREST LAND BASE

Arkansas' total forest land-base decreased from 19.9 million acres in 1962 to about 16 million acres in 1985 (U.S.D.A., 1987) (Table 1). Future reductions will probably lower the forest base to about 14.4 million acres by 2030. Reductions in the past were attributable to three principal causes. First, there was large scale agricultural clearing in the Delta (1960-1975). Most of this clearing removed bottomland hardwood stands. Second, many upland hardwood stands were cleared for grazing, especially in the Ozark Region (1970s). Finally, many of the other stands were cleared for urban development. Future removals from the forest base will most likely be for increased urbanization and industrialization.

Forest acreage reductions were primarily in the private nonindustrial landowner sector (Table 2). Acreages owned by the private forest industry (Table 3) and the public sectors (Table 4) have remained nearly stable, so they now comprise a larger percent of the total state forest area. In the late 1950's, private non-industrial forest landowners held almost 70% of Arkansas' total timberland. By 1985, however, private nonindustrial forest landowner's holdings had decreased to 54% (Table 5). In 1985, private forest industry held 27% and public ownerships 18%. We project that by 2030 Arkansas will have 14.4 million forested acres of which 47% will be owned by private nonindustrial landowners, 31% in private industry and 22% by the public (previously unpublished projections developed by the Arkansas Timber Study Committee, 1988; U.S.D.A., 1987).

### CHANGING MANAGEMENT TYPES

With the shift in control of forest lands has come a change in the nature of Arkansas' forest. The management styles of private forest industry and private nonindustrial forest landowners differ. Consequently, the distribution of forested acres by management type has also changed.

Acreage changes have occurred in all management types (Table 1). Decreases have occurred in the upland hardwood management group

<table>
<thead>
<tr>
<th>Year</th>
<th>Plantations</th>
<th>Natural</th>
<th>Mixed Pine</th>
<th>Hardwood</th>
</tr>
</thead>
<tbody>
<tr>
<td>1952</td>
<td>21</td>
<td>1693</td>
<td>617</td>
<td>1114</td>
</tr>
<tr>
<td>1962</td>
<td>57</td>
<td>1631</td>
<td>650</td>
<td>951</td>
</tr>
<tr>
<td>1970</td>
<td>110</td>
<td>1554</td>
<td>912</td>
<td>609</td>
</tr>
<tr>
<td>1977</td>
<td>186</td>
<td>1613</td>
<td>912</td>
<td>667</td>
</tr>
<tr>
<td>1985</td>
<td>681</td>
<td>1392</td>
<td>909</td>
<td>603</td>
</tr>
<tr>
<td>1990</td>
<td>1321</td>
<td>1778</td>
<td>910</td>
<td>686</td>
</tr>
<tr>
<td>2000</td>
<td>2088</td>
<td>648</td>
<td>433</td>
<td>587</td>
</tr>
<tr>
<td>2010</td>
<td>2447</td>
<td>533</td>
<td>352</td>
<td>510</td>
</tr>
<tr>
<td>2020</td>
<td>2602</td>
<td>513</td>
<td>326</td>
<td>457</td>
</tr>
<tr>
<td>2030</td>
<td>2693</td>
<td>509</td>
<td>330</td>
<td>427</td>
</tr>
</tbody>
</table>

Arkansas' Timber Resource: Yesterday, Today and Tomorrow

Table 5. Distribution of growing stock, supply, and 1985 Growth:Drain ratios across landowners in Arkansas.

<table>
<thead>
<tr>
<th>Landowner Group</th>
<th>Private Forest</th>
<th>Private Industry</th>
<th>Private Nonindustrial</th>
<th>Public</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acres Owned (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Softwood Inventory (%)</td>
<td>39</td>
<td>40</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>Softwood Supply (%)</td>
<td>51</td>
<td>39</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Softwood Growth:Drain Ratio</td>
<td>1.16</td>
<td>1.52</td>
<td>1.29</td>
<td></td>
</tr>
<tr>
<td>Hardwood Inventory (%)</td>
<td>23</td>
<td>56</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>Hardwood Supply (%)</td>
<td>29</td>
<td>62</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Hardwood Growth:Drain Ratio</td>
<td>1.98</td>
<td>2.26</td>
<td>4.36</td>
<td></td>
</tr>
<tr>
<td>Total Inventory (%)</td>
<td>30</td>
<td>49</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>Total Supply (%)</td>
<td>44</td>
<td>47</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Total Growth:Drain Ratio</td>
<td>1.34</td>
<td>1.84</td>
<td>2.63</td>
<td></td>
</tr>
</tbody>
</table>


1 Growth: Drain is the proportion of yearly forest growth removed in harvesting and other removals from the forest.

7% (2030). The acreage of both upland and bottomland hardwoods has been relatively stable since 1970 and now amount to 14% and 18% respectively on private forest industry lands. However, it is estimated that in 2030 upland and bottomland hardwoods will decrease to 10% and 11% respectively (U.S.D.A., 1987; previously unpublished projections developed by the Arkansas Timber Study Committee, 1988).

In 1983, 3% of private nonindustrial forest lands were in plantations (U.S.D.A., 1987) (Table 3). That may increase to nearly 8% by 2030 (previously unpublished projections developed by the Arkansas Timber Study Committee, 1988). During the same period natural pine stands will probably decrease from 14% to about 12%. Mixed pine-hardwood and upland hardwood stands will remain at about 13% and 45%, respectively, in 2030.

Management types on public lands should not change significantly over the period of the analysis (Table 4). Of total public acreage, plantations will account for roughly 3%, natural pine about 24%, mixed pine-hardwood about 24%, upland hardwood about 35% and bottomland hardwoods about 13% (previously unpublished projections developed by the Arkansas Timber Study Committee, 1988).

INVENTORY AND NET ANNUAL GROWTH

Softwood

Softwood inventories in the state should continue to increase until about 1990, and then begin a slow decline. This will happen due to volume increases in older plantations coming to harvest age followed by harvesting in these same plantations. Increasing harvest and other removals will exceed declining softwood net annual growth by 1990 if Forest Service projections are correct.

Private forest industry will increase its harvest while converting natural pine stands to pine plantations with higher stocking. The trend of softwood timber growth dropping below timber drain could continue until about 2020. For some time softwood net annual growth rates have been declining on both industrial and nonindustrial private lands. In the next few years, removals will exceed net annual growth for the private sector. However, projections indicate that softwood growth:drain ratios (net annual forest growth divided by harvest removals) will once again approach 1:1 by about 2020 (U.S.D.A., 1987).

Hardwood

Hardwood inventories in the state decreased in the 1970s and then began to increase. Projections indicate that hardwood inventory will peak around 2000 and then decline (U.S.D.A., 1987). Hardwood removals peaked in the early 1970s, coinciding with large scale agricultural clearings. The largest inventory declines were in the private nonindustrial forest landowner sector. Hardwood net annual growth will fall below harvest beginning about the year 2000 if present cutting practices continue. Private forest industry removals of hardwood often coincides with the conversion of upland hardwood and mixed pine-hardwood stands to pine. Continued removal of hardwood at the present rate will reduce industry hardwood growing stock to the point that harvest will begin to exceed net annual growth by the year 2005 (U.S.D.A., 1987).

Hardwood inventory levels on private nonindustrial forest lands reflect a continued removal of less than growth until 1990. This may be followed by harvest exceeding net annual growth in the late 1990s. Harbors and other removals could continue to exceed growth until the end of the analysis period.

Public lands will continue to provide a major portion of hardwood supplies. In particular, the large Ozark and Ouachita National Forest hardwood resource will continue to provide at a high rate (previously unpublished projections developed by the Arkansas Timber Study Committee, 1988).

STOCKING LEVELS AND STOCKING PROBLEMS

Over half of Arkansas' forest acres are at least 85% stocked with trees that are not rough or rotten (van Hees, 1980). Over three-fourth carry 70% or better stocking. However, less than a third of the total forest acres carry 25% or better stocking of silviculturally desirable trees (i.e., the type that foresters would favor). In addition, only 50% of the state's forest acres are better than 70% stocked with trees that are acceptable (they meet the requirements of growing stock trees, but not of being desirable) (van Hees, 1980). In short, Arkansas forest lands carry relatively high total stocking levels, but little of the forest land may be characterized as having commercially desirable or acceptable trees growing on it (van Hees, 1980; Birdseye et al., 1981).

In general, the most serious problems with low quality growing stock are on private nonindustrial ownerships. Many of these owners have repeatedly harvested the better pine and hardwood trees while leaving the undesirable trees. On pine lands, low quality understory hardwoods are often allowed to dominate the site after pines are harvested. Private forest industry lands, on the other hand, are generally in good condition in regard to the quality of growing stock. As a rule, the companies eliminate cull and undesirable trees in both their hardwoods and pine stands. On pine lands they control undesirable hardwoods to insure that pines continue to dominate the site. Regardless of species and class, most Arkansas sites are of sufficiently high quality to support greater inventory, growth and harvest levels. This is especially true in the pine and mixed pine-hardwood areas of the state.

METHODS OF INCREASING THE FUTURE TIMBER SUPPLY

Arkansas' timber production could be increased by manipulating site quality, stocking level, and the quality of growing stock on the site. Each of these factors is controllable to some degree. Control, however, will require investments of time and money. Just under 40% of the total forest acres in Arkansas are in need of some cultural treatment to improve productivity. The majority (60%) of these 6.5 million acres are private forest industry lands (22%), and public holdings (18%). The 6.6 million acres that could benefit from cultural treatment fall into two categories. First, there are about 2.0 million acres that have never been actively managed, but have a high potential for increased production of timber. These acres could yield a return of at least 10 percent (real, net of inflation) on the required investment (U.S.D.A., 1987). The total cost of treating these 2.0 million acres would be about $184 million, or an average cost of $92 per acre (U.S.D.A., 1987). The increased timber yield on these acres would amount to an additional 105 million cubic feet of net annual growth. This would amount of over 52 cubic feet per acre per year. The majority of the acres in this category are on private nonindustrial forest lands.

Second, there are approximately 2.75 million additional acres which could yield a real return of at least 4 percent but less than 10 percent on the cost of applying cultural treatments to correct stand deficiencies (U.S.D.A., 1987). The total cost of treating these 2.75 million acres would be $330 million, or an average $127 per acre. The estimated net annual growth increase would total 108 million cubic feet, or an addi-
if forest investment is to be competitive. Third, improve markets for forest products. Research should be continued to develop forest products compatible with the long term timber resource of the state. In addition, export markets for Arkansas forest products should be pursued to provide additional outlets for Arkansas' products. Fourth, overcome factors restricting the development of Arkansas resources. Arkansas forest landowners need to be provided with continuing educational services to enable them to make good decisions. The major problems to be dealt with in bringing about major changes to the states' forests are not technical questions but rather turning individual landowners into active forest managers. Better road systems need to be provided into undeveloped but heavily timbered areas of the state. Better access will improve markets and the forest resource to management as it is in other places in the state.

LITERATURE CITED


R. A. Kluender and R. L. Willett

FUTURE PRODUCTION FROM ARKANSAS' FORESTS

The Arkansas Timber Study Committee estimates that production will rise to 620 million cubic feet by 1990 (up 14% from 1985), and to 725 million cubic feet by 2030 (up 34% from 1985) (Figure 1). It is probable that an increasing number of unmanaged private nonindustrial lands will come under management for the first time in the next five to ten years. Many landowners will use natural regeneration or low cost-low intensity methods of artificial regeneration. Many will elect uneven-aged management schemes. Several facts have lead us to these projections. The most important of these facts are as follows. First, there is an increasing tendency of landowners to manage for products that have a higher marketplace value (e.g. sawlogs rather than pulpwood). Second, both natural regeneration and uneven-aged management have lower initial cost than artificial regeneration. Third, there continues to be an intense interest by private nonindustrial forest landowners in non-timber forest values. These values are perceived to be at variance with some plantation management techniques. Fourth, uneven-aged management allows for frequent income flows from the forest investment. Fifth, many of the under-managed or non-managed sites in Arkansas are not well suited to intensive forest management practices due to site conditions or small tract size. Sixth, there are an increasing number of Arkansas landowners who are willing to perform forest management work on their land themselves.

After intensive study, the Arkansas Timber Study Committee makes the following suggestions in four areas for increasing long term supply from the state's forest lands. First, improve and control stocking on all forest land in the state. This can be done by gradually replacing undesirable and unmerchantable stems with high quality growing stock. Desirable crop trees should also be released to grow free of competition. Second, increase the quality of forest investment opportunities. Low initial cost investment alternatives should be used on both industrial and private lands when ever possible. Qualifying landowners should utilize incentive programs such as FIP, CRP, etc. that can offer significant cost reductions and provide for higher internal rates of return on investments. Landowners should use the planning and management assistance that is available from public and private sectors of the forestry community to aid in decision making. Also the taxation climate for timber investment at the state and federal level needs to be improved.

Figure 1. Past USFS projected, and Arkansas Timber Study Committee projected, production for Arkansas forests. Source: Kluender et al., 1988; USDA, 1987; Arkansas Timber Study Committee, 1988.
ASSOCIATION OF MESOCOTYL AND COLEOPTILE ELONGATION WITH SEEDLING VIGOR IN RICE

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ABSTRACT

Three experiments were conducted to evaluate the relationship of mesocotyl and coleoptile elongation to seedling vigor and plant height in rice (Oryza sativa). A laboratory experiment was conducted to evaluate the potential lengths of the mesocotyl and coleoptile of semidwarf and standard rice genotypes. Four genotypes exhibited inherent differences in their ability for mesocotyl and coleoptile elongation. The semidwarf genotypes ('M-101' and RU 7703008) showed reduced mesocotyls, coleoptiles, and total lengths (mesocotyl + coleoptile); whereas, the tall plant type ('L-201' and 'Labelle') had comparatively longer mesocotyls, coleoptiles, and total lengths. It is assumed that mesocotyl elongation is the most important of the three parameters evaluated in seedling vigor, but total length is the least variable. Significant differences were detected among seeding depths and genotypes in the greenhouse experiment for emergence percentage, emergence index, coleoptile, and mesocotyl lengths. The field experiment verified that the low seedling vigor was due to the shorter mesocotyls and coleoptiles of the semidwarf genotypes in this test and was primarily responsible for poor stand establishment.

INTRODUCTION

Dwarf genotypes of wheat (Triticum aestivum L. em. Thell.) that were developed in Mexico by N.E. Borloug in the 1970's have doubled wheat yields in many countries and contributed to the "Green Revolution". Similar advances have been made in rice (Oryza sativa L.) with the release of dwarf and semidwarf genotypes. Short-statured genotypes are desirable for their increased lodging resistance and high nitrogen responsiveness which usually increase grain yield (Hargrove et al., 1980; Mikkelsen and Dedatta, 1980).

Plant population is a major yield component and is often directly dependent upon seedling vigor and stand establishment. However, difficulties in establishing a stand of short-statured rice have been associated primarily with the germplasm that has been used in breeding programs to develop semidwarf genotypes (Dalyryme, 1980). Also, seedling emergence problems have been associated with the short-statured phenotype in winter wheat after deep seeding. The coleoptile ruptures below the soil surface and does not allow the leaves to push through the soil (Sunderman, 1964). Research on semidwarf rice genotypes have indicated that reduced mesocotyl elongation seems to hinder seedling emergence and, consequently, leads to poor stand establishment (Turner et al., 1982). Therefore, the mesocotyl and coleoptile have a major role in stand establishment of most monocotyledonous plants.

The mesocotyl is the internode between the coleoptile node and the point of union of the root and the culm. The mesocotyl (internode) only elongates in the dark; therefore, its length can be measured only when the seedlings have been grown in a dark environment (e.g., growth chamber or underground). The elongation of the mesocotyl elevates the coleoptile, which is the protective sheath enclosing the young leaves, above ground. Nagai (1958) used mesocotyl and coleoptile lengths to differentiate genotypes and indicated that the two traits could serve as indices of seedling vigor.

Knowledge of the relationship between the mesocotyl, coleoptile, and plant height is essential for breeders to incorporate semidwarf genes into new and adapted rice genotypes. The objectives of the present study were to: a) determine the length of the mesocotyl and coleoptile of two semidwarf and two standard rice genotypes; b) compare the mesocotyl/coleoptile elongation phenomenon in laboratory, greenhouse, and field conditions; c) determine the effect of seedling depth of the genotypes on mesocotyl and coleoptile elongation; d) and examine the relationship between mesocotyl/coleoptile elongation, percentage emergence, and plant height.

MATERIALS AND METHODS

In this study three rice genotypes and one experimental line, all of diverse origin, were evaluated. The semidwarf genotypes were 'M-101' (an early maturing California genotype) and RU 7703008 (a sister line of a USDA-Texas Agricultural Experiment Station midseason genotype 'Bellermine'). The other two genotypes of comparatively taller stature were 'Labelle', a genotype developed by USDA and the Texas Agriculture Experiment Station, and 'L-201' (an early maturing genotype developed by the California Cooperative Rice Research Foundation). Three experiments were conducted at the Rice Research and Extension Center near Stuttgart, Arkansas.

LABORATORY, GREENHOUSE, AND FIELD EXPERIMENTS

A laboratory test was designed to determine the potential length of the mesocotyl and coleoptile of the four genotypes and to test the visibility of the seed. In this test, a modification of the slantboard technique described by Jones and Peterson (1976) was used. Moistened blotters (15 x 20 cm) were placed on acrylic plates of the same size and twenty seeds were placed on the blotters approximately one cm apart, germ-end down along a horizontal line 4.5 cm from the bottom edge of the blotters.

The seeds were held in position by a single thickness tissue that was moistened with distilled water. Plates, blotters, and adhering seed were placed in slotted racks that were made of acrylic plastic. Each rack held 15 plates. The entire assembly was placed in aluminum trays that contained enough distilled water to keep the lower edge of the blotters continuously wet. The trays were wrapped in black polyethylene bags to maintain high humidity, eliminate evaporative cooling, and to provide a dark environment because of the effect of light on mesocotyl/coleoptile elongation. The trays were placed in a temperature-controlled germinator for 10 days (at 25 ± 1.0°C), after which the mesocotyl and coleoptile lengths were measured. Abnormal or diseased seedling data were also recorded for percent germination, but their mesocotyl and coleoptile lengths were not measured because of abnormal growth and development of those seedlings.

The greenhouse test was designed to determine the effect of seedling depth and genotype on mesocotyl/coleoptile length and their subsequent influence on seedling emergence. A split-plot design with four replications was used. Seven seeding depths ranging from 1.3 to 8.9 cm (increments of 1.25 cm) were handled as main plots, and the four genotypes were sub-plots. Aluminum trays were lined with single thickness paper. Soil was added to the trays and uniformly spread to provide a thin layer on which the seeds could be planted. Each tray represented a particular
seeding depth. Four rows were marked in each tray and the genotypes were randomly assigned. Thirty seeds per row were planted and a marked garden label was placed vertically to attain the required seeding depth for each tray. Water was added at regular intervals to maintain adequate soil moisture for seed germination. Seedling emergence started on the fourth day after seeding and seedling counts were taken daily for eight days. The total number of seedlings for a particular day minus the previous total equaled the seedling emergence for an individual day. This information was used to determine the emergence percentage and emergence index (EI). The formula used to determine EI was the one used by Jones and Peterson (1976) and McKenzie et al., (1980). The EI provides a weighted score for both early emergence and high emergence percentage.

A field experiment designed to complement the laboratory and greenhouse experiments was conducted. The four genotypes were seeded on a Cowboy silt loam soil, a fine montmorillonitic thermic Typic Albaqualf. The seeding depths were randomly assigned to the main plots and each main plot was replicated six times. The land was prepared and rolled so the soil was uniformly compact and essentially level. This allowed for uniform planting depth. Thirty mature seeds were planted in each row with a cone planter. To minimize variability of the main plots between replications due to planter effect, the planter plates were adjusted for each planting depth for each main plot. The seeding depths of 1.3, 2.5, 3.8, 5.1, 6.4 and 7.6 cm were tested. Rows were 18 cm apart and 1.5 m long. Propanil was applied two weeks after seeding at the rate of 9.3 kg/ha for weed control. Urea fertilizer was applied at the rate of 133 kg of NH3/ha in three split applications. The first fertilizer application was made three weeks after seeding and a 5 to 8 cm flood was applied and maintained until maturity. The number of emerged seedlings 20 days after seeding was recorded.

Statistical analysis of greenhouse and field data was accomplished by using SAS procedures of the General Linear Model and Analysis of Variance. Multivariate statistics were necessary because the model statements included more than one dependent variable (Helwig, 1979). Mean separations were by Duncan’s Multiple Range Test (1955).

Table 1. Mean separation for coleoptile, mesocotyl and total length laboratory experiment.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Mesocotyl Lengths in cm</th>
<th>Coleoptile Lengths</th>
</tr>
</thead>
<tbody>
<tr>
<td>M-101</td>
<td>2.1</td>
<td>26.7</td>
</tr>
<tr>
<td>RU 7703008</td>
<td>1.6</td>
<td>13.4</td>
</tr>
<tr>
<td>L-201</td>
<td>16.9</td>
<td>31.6</td>
</tr>
<tr>
<td>Labelle</td>
<td>15.9</td>
<td>20.7</td>
</tr>
<tr>
<td>LSD</td>
<td>0.05</td>
<td>2.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7.6</td>
</tr>
</tbody>
</table>

RESULTS AND DISCUSSION

The four genotypes differed significantly in mesocotyl, coleoptile and total length (Table 1). The mesocotyl and total lengths of M-101 and RU 7703008 were significantly shorter than those of L-201 and Labelle. This supported the assumption by Turner et al. (1982) that dwarf genotypes have shorter mesocotyl and total lengths as compared to standard genotypes. These data also showed that genotypes exhibit different potential for mesocotyl and coleoptile lengths and that differences in mesocotyl and coleoptile lengths can be selected by breeders in subsequent development of semidwarf genotypes for drill-seeded rice.

Emergence Percentage: A significant effect on seedling emergence was observed between seeding depths and genotypes (Table 2 and 3). The genotype differences could be attributed to their inherent mesocotyl and coleoptile length differences. Genotypes with the greatest total length (mesocotyl and coleoptile) in the laboratory test had correspondingly higher emergence percentage at deep seeding in the greenhouse experiment. However, there was a consistent decrease in the emergence percentage as seeding depth increased.

Each genotype had a threshold seeding depth and many shallower depths gave an adequate stand establishment. Most seedling mortality occurred before emergence, therefore, emergence percentage was one indicator of seedling vigor. This verified the assumption that the short-statured genotypes used in this test were less vigorous based on emergence and subsequent growth and development as compared to the standard genotypes, especially at deeper seeding.

Mesocotyl, Coleoptile, and Total Length. Significant differences among mesocotyl, coleoptile, and total length due to seeding depths and genotypes were detected (Table 4 and 6). The mesocotyl and coleoptile of L-201 and Labelle showed greater elongation potential than did M-101 and RU 7703008. These data agree with those of Mers’ (1979) who found that in oats the reduction in mesocotyl growth was accomplished by a transient promotion of coleoptile growth that was apparently due to a reduction in auxin.
Table 4. Mesocotyl lengths of four genotypes at seven different seeding depths greenhouse experiment.

<table>
<thead>
<tr>
<th>Seeding depth (cm)</th>
<th>Genotype</th>
<th>Mesocotyl/Length (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M-101</td>
<td>7703008</td>
</tr>
<tr>
<td>1.3</td>
<td>2.1</td>
<td>2.2</td>
</tr>
<tr>
<td>2.5</td>
<td>2.4</td>
<td>1.9</td>
</tr>
<tr>
<td>3.8</td>
<td>3.2</td>
<td>1.7</td>
</tr>
<tr>
<td>5.1</td>
<td>5.7</td>
<td>2.9</td>
</tr>
<tr>
<td>6.4</td>
<td>3.3</td>
<td>2.2</td>
</tr>
<tr>
<td>7.6</td>
<td>7.2</td>
<td>1.5</td>
</tr>
<tr>
<td>8.9</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Cultivar Mean: 3.4, 1.8, 18.2, 23.6

LSD for seeding depth differences = 8.4, 0.05
LSD for genotype differences = 2.1, 0.05

Table 5. Coleoptile lengths of four genotypes at seven different seeding depths greenhouse experiment.

<table>
<thead>
<tr>
<th>Seeding depths (cm)</th>
<th>Genotype</th>
<th>Coleoptile/Length (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M-101</td>
<td>7703008</td>
</tr>
<tr>
<td>1.3</td>
<td>11.6</td>
<td>12.2</td>
</tr>
<tr>
<td>2.5</td>
<td>20.1</td>
<td>20.1</td>
</tr>
<tr>
<td>3.8</td>
<td>26.6</td>
<td>19.5</td>
</tr>
<tr>
<td>5.1</td>
<td>37.4</td>
<td>38.2</td>
</tr>
<tr>
<td>6.4</td>
<td>26.6</td>
<td>27.2</td>
</tr>
<tr>
<td>7.6</td>
<td>40.2</td>
<td>16.0</td>
</tr>
<tr>
<td>8.9</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Cultivar Mean: 23.2, 19.0, 23.1, 19.6

LSD for seeding depth differences = 12.5, 0.05
LSD for genotype differences = 2.8, 0.05

Table 6. Arctan emergence percent of the four genotypes planted at six seeding depths field experiment.

<table>
<thead>
<tr>
<th>Seeding depth (cm)</th>
<th>Genotype</th>
<th>Arctan %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M-101</td>
<td>7703008</td>
</tr>
<tr>
<td>1.3</td>
<td>44.1</td>
<td>88.2</td>
</tr>
<tr>
<td>2.5</td>
<td>36.5</td>
<td>78.2</td>
</tr>
<tr>
<td>3.8</td>
<td>32.4</td>
<td>58.3</td>
</tr>
<tr>
<td>5.1</td>
<td>23.0</td>
<td>40.1</td>
</tr>
<tr>
<td>6.4</td>
<td>24.8</td>
<td>28.1</td>
</tr>
<tr>
<td>7.6</td>
<td>18.9</td>
<td>28.2</td>
</tr>
</tbody>
</table>

Cultivar average: 30.0 d, 53.5 c, 93.1 a, 87.0 b

Means followed by same letter are not statistically different at the 0.05 level of probability.

Total length (mesocotyl + coleoptile) is an important factor in seedling vigor. Emergence occurs only when the coleoptile tip brings the primary leaf to the surface of the soil, which is a combined effect of the mesocotyl and coleoptile. Data from this study and Turner et al. (1982) agree that total length is a more valuable parameter in seedling vigor studies than mesocotyl or coleoptile length alone. This assumption is based primarily on lower variability of the total length versus the variability of the mesocotyl or coleoptile length measured separately. For example, the coefficient of variability (CV) of the mesocotyl, coleoptile, and total length of both the laboratory and greenhouse tests were 38.2, 16.5 and 9.6 versus 32.8, 24.6, and 19.7%, respectively. The short-statured genotypes, M-101 and RU 7703008, showed a decrease in total length at deeper seedings, which indicates that emergence is impaired at deep seeding. Cultivars, L-201 and Labelle, which showed greater potential for mesocotyl elongation also exhibited higher emergence percentage. These data show that the mesocotyl, though highly variable, contributes more than the coleoptile to seedling vigor at deeper seeding depths.

This experiment was conducted to determine the relationship between the mesocotyl and coleoptile elongation in the laboratory and greenhouse experiments versus seedling emergence and plant height at maturity in field conditions. Analysis of variance detected significant differences among genotypes for seedling emergence and plant height. Significant differences are also detected among seedings for seedling emergence percent.

The genotypes M-101 and RU 7703008 showed poorer seedling emergence in the field experiment than in the greenhouse. This was probably due to soil compaction of the Crowley silt loam soil in the field after heavy rains (Table 6). A bar diagram showed significant differences between plant height and mesocotyl lengths by genotype (Fig. 1). Figure 1 shows that the short-statured genotypes M-101 and RU 7703008 exhibit reduced mesocotyl lengths and plant heights; whereas, L-201 and Labelle (tall plant types) had comparatively longer mesocotyls. This trend is a major concern among breeders because of the possibility of a pleiotropic effect of mesocotyl/coleoptile elongation and plant height. Furthermore, the assumption of many rice breeders that short-statured plants have a short mesocotyl and low total length which accounts for their low emergence percentage at deeper seeding is supported by these data. The opposite appears to be true for the tall phenotypes.

![Figure 1](http://scholarworks.uark.edu/jaas/vol42/iss1/1)


AUTUMN FOODS OF WHITE-TAILED DEER IN ARKANSAS

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ABSTRACT

Rumen contents from 65 hunter-harvested deer were collected and analyzed during 1985-86 to estimate the principal autumn foods consumed by white-tailed deer inhabiting the Ozark Mountains, Arkansas River Valley, and Gulf Coastal Plain regions of Arkansas. Deer in the Ozarks and Coastal Plain fed heavily on woody browse species, which comprised 99% of rumina identified from these 2 regions. Acorns were the primary food of deer in these heavily forested areas. Acorns and other woody browse were less important to deer inhabiting the Arkansas River Valley. This region of interspersed agricultural fields and bottomland forests, soybeans and corn comprised 75% of the diet, and acorns accounted for only 2%.

INTRODUCTION

The principal food consumed by white-tailed deer (Odocoileus Virginianus) have been well documented in many southern states (Korschgen, 1962; Lay, 1965; Harlow et al., 1975). However, little information is available on the food habits of deer in Arkansas, and no studies have been conducted to compare the diets of deer inhabiting varying ecoregions of the state. A prior study reported important fall foods of deer inhabiting the Ouachita Mountains (Fenwood et al., 1985); however, no published data are available describing deer food habits in three other ecoregions: the Ozark Mountains, Arkansas River Valley, and Gulf Coastal Plain. Such information is useful for habitat improvement and for the assessment of range quality. The purpose of this report is to compare and contrast the autumn diets of deer inhabiting these three ecoregions.

MATERIALS AND METHODS

During November of 1985 and 1986, rumen samples were collected from 65 hunter-harvested deer at locations representative of each ecoregion. Ruminas were collected from 21 deer harvested in Carroll Co., located in the mixed pine-hardwood forests of the Gulf Coastal Plain. Assessment of the diet of deer in the Arkansas River Valley was based on samples from 32 deer collected on Holla Bend National Wildlife Refuge in Pope Co. Holla Bend supports both bottomland hardwoods and extensive agricultural fields, a mixed habitat that is characteristic of much of the Valley. Twelve deer were collected on the Sylamore Wildlife Management Area in Stone and Baxter Counties, an area of the Ozark Mountains dominated by oak-hickory forests. Approximately 3 L of rumina were collected from each deer; samples were labelled and stored frozen for subsequent analyses. Each sample was washed through a standard 9.51-mm mesh sieve to remove materials too small for analysis. Prior research demonstrated that this size screen provides a reasonable estimate of most food items present in the rumen (Harlow and Hooper, 1971). Suspended food items were separated by species or genus; the portion of each plant consumed (leaves, stems, or fruits) and its volume (measured by water displacement) were recorded. The importance of each food item to deer was based on its relative volume and frequency of occurrence in these rumens.

RESULTS AND DISCUSSION

All of the deer collected in the Ozarks fed heavily on acorns, which comprised over 90% of the fall diet (Table 1). Fruits and vegetative parts of woody species made-up 98% of the foods identified from these individuals. Woody vines, such as greenbriers (Smithax spp.) and grapes (Vitis spp.) occurred frequently in these deer, but seldom constituted more than 5% of the total volume in any rumen. Small volumes of sumac (Rhus glabra, R. copallina) were also common. Although eastern redbud (Juniperus Virginiana) is considered to be a preferred fall food of deer in Missouri (Murphy and Crawford, 1970), and occurs in scattered glades throughout the Ozarks, the species was not found in our samples.

Deer inhabiting the mixed pine-hardwood forests of the Coastal Plain had an autumn diet similar to that of deer in the Ozarks. Acorns predominated in the rumina of these individuals (Table 1); 28 of 31 individuals sampled had fed primarily (87.1%) on acorns. Other woody plants that were commonly eaten in this region included Japanese honeysuckle (Lonicera japonica), greenbriers, and sumac. Deer harvested in the Arkansas River Valley fed on a very different diet than deer inhabiting other regions (Table 1). Agricultural plants, particularly soybeans and corn, comprised the major component of the diet of these deer. Although the fruits of these species appeared to be the most preferred plant part, leaves and stems of both species were commonly consumed. Primary woody plants consumed included: honeysuckle, hackberry (Celtis occidentalis), sumac, greenbriers, and grapes. Although some oaks do occur on Holla Bend, they are not common. Consequently, acorns were not an important component of the diet of these deer. While woody plants comprised approximately 98% of the volume of food consumed by deer in the Ozarks and Gulf Coastal Plain areas, only 21% of the diet among Arkansas River Valley deer was from woody species.

Acorn production in Arkansas forests was high during the two years of this study. We speculate that in years of poor production, deer would rely more heavily on woody species such as greenbriers, grapes, and sumac that were present at low levels in our samples. Fenwood et al., (1985) reported that acorns averaged 65% (by volume) of the food consumed by deer in the Ouachita Mountains in a good mast year, but were absent in a year of mast failure.

Our results suggest that deer managers interested in assessing deer densities relative to available food supplies could use greenbriers, sumacs, and grapes as "indicator species" for browse utilization surveys. All of these foods were consumed in each ecoregion studied, and were used even when acorns, soybeans, or corn were abundant. It is important to note however, that the extent that deer use these "indicator species" will vary among regions and among years, depending on the availability of acorns, crops, and other preferred foods. Management practices which encourage a diversity of understory browse species should help to buffer food supplies during years of poor mast production.
### Table 1. Volume (and frequency) of principal foods found in rumens of white-tailed deer harvested in the Ozark Mountain, Gulf Coastal Plain, and Arkansas River Valley regions of Arkansas, November 1985 and 1986.

<table>
<thead>
<tr>
<th>Food Items and Parts Eaten</th>
<th>Ozarks</th>
<th>Gulf Coastal Plain</th>
<th>Arkansas River Valley</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oak (Quercus spp.) acorns</td>
<td>91.0 (100)</td>
<td>87.3 (90)</td>
<td>2.1 (3)</td>
</tr>
<tr>
<td>Scybeans (Glycine max) fruits, leaves, stems</td>
<td>-</td>
<td>-</td>
<td>61.3 (81)</td>
</tr>
<tr>
<td>Corn (Zea mays) fruit, leaves, stems</td>
<td>-</td>
<td>-</td>
<td>13.8 (44)</td>
</tr>
<tr>
<td>Honeysuckle (Lonicera japonica) leaves, stems</td>
<td>0.2 (17)</td>
<td>0.9 (43)</td>
<td>9.6 (38)</td>
</tr>
<tr>
<td>Hackberry (Celtis occidentalis) fruits</td>
<td>-</td>
<td>-</td>
<td>5.0 (3)</td>
</tr>
<tr>
<td>Sumac (Rhus spp.) leaves, stems</td>
<td>0.9 (50)</td>
<td>2.2 (19)</td>
<td>1.3 (6)</td>
</tr>
<tr>
<td>Greenbriers (Smilax spp.) leaves, stems</td>
<td>1.1 (50)</td>
<td>0.6 (76)</td>
<td>0.6 (9)</td>
</tr>
<tr>
<td>Unidentified leaves and stems</td>
<td>3.5 (50)</td>
<td>1.0 (57)</td>
<td>0.9 (16)</td>
</tr>
<tr>
<td>Partridge pea (Cassia fasciculata) fruits, stems</td>
<td>-</td>
<td>-</td>
<td>2.7 (3)</td>
</tr>
<tr>
<td>Black cherry (Prunus serotina) leaves</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Fungi</td>
<td>0.4 (8)</td>
<td>1.0 (71)</td>
<td>-</td>
</tr>
<tr>
<td>Grapes (Vitis spp.) fruits, leaves, stems</td>
<td>0.9 (17)</td>
<td>0.2 (10)</td>
<td>0.5 (6)</td>
</tr>
<tr>
<td>Winged elm (Ulmus alata) leaves</td>
<td>0.8 (8)</td>
<td>0.2 (6)</td>
<td>0.3 (14)</td>
</tr>
<tr>
<td>Grass and/or grass-like leaves</td>
<td>0.4 (83)</td>
<td>0.3 (43)</td>
<td>0.3 (9)</td>
</tr>
<tr>
<td>Goldenrods (Solidago spp.) leaves</td>
<td>0.8 (8)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Rattanvines (Berchemia scandens) fruits</td>
<td>-</td>
<td>0.4 (3)</td>
<td>0.1 (5)</td>
</tr>
<tr>
<td>Flowering dogwood (Cornus florida) leaves</td>
<td>&lt;0.1 (17)</td>
<td>0.3 (10)</td>
<td>-</td>
</tr>
<tr>
<td>Cross-vine (Bignonia capreolata) leaves, stems</td>
<td>-</td>
<td>0.3 (14)</td>
<td>-</td>
</tr>
<tr>
<td>Gum buxus (Buxus laevigata) fruits</td>
<td>-</td>
<td>-</td>
<td>0.3 (6)</td>
</tr>
<tr>
<td>Elderberry (Sambucus canadensis) fruits</td>
<td>-</td>
<td>-</td>
<td>0.3 (3)</td>
</tr>
<tr>
<td>Blueberries (Vaccinium spp.) leaves, stems</td>
<td>&lt;0.1 (8)</td>
<td>0.2 (14)</td>
<td>-</td>
</tr>
<tr>
<td>Poison ivy (Toxicodendron radicans) leaves</td>
<td>-</td>
<td>0.2 (10)</td>
<td>&lt;0.1 (6)</td>
</tr>
<tr>
<td>Osage orange (Maclura pomifera) Fruits</td>
<td>-</td>
<td>-</td>
<td>0.2 (3)</td>
</tr>
<tr>
<td>Ground cherry (Physalis heterophylla) fruits</td>
<td>-</td>
<td>-</td>
<td>0.2 (3)</td>
</tr>
<tr>
<td>Soapberry (Sapindus drummondii) fruits</td>
<td>-</td>
<td>-</td>
<td>0.2 (3)</td>
</tr>
<tr>
<td>Possum haw (Ilex decidua) fruits</td>
<td>-</td>
<td>0.2 (10)</td>
<td>-</td>
</tr>
<tr>
<td>Buckbrush (Symphoricarpus orbiculatus)</td>
<td>&lt;0.1 (33)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Morning glory (Convolvulus spp.) leaves, stems</td>
<td>-</td>
<td>-</td>
<td>0.1 (9)</td>
</tr>
<tr>
<td>American elm (Ulmus americana) leaves</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Box elder (Acer negundo) leaves</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Devil's walkingstick (Aralia spinosa) leaves</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Red mulberry (Morus rubra) leaves</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sugarberry (Celtis laevigata) leaves</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Wild plum (Prunus texana) leaves</td>
<td>&lt;0.1 (17)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Ironwood (Ostrya virginiana) leaves</td>
<td>&lt;0.1 (8)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Blackhawk (Viburnum spp.) leaves</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Black willow (Saliix nigra) leaves</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>American holly (Ilex decidua) leaves</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Pine (Pinus spp.) leaves</td>
<td>&lt;0.1 (5)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Carolina moonseed (Cocculus carolinus) leaves</td>
<td>&lt;0.1 (5)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Partridgeberry (Mitchella repens) leaves</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Beaggarweeds (Desmodium spp.) leaves</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Canebrack (Salvia lyrata) leaves</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

### ACKNOWLEDGEMENTS

Funding for this study was provided by the National Park Service, the Ross Foundation, and Arkansas Tech University. The authors wish to thank Mike Cartwright and Donny Harris, Arkansas Game and Fish Commission; Martin Perry, U.S. Fish and Wildlife Service; and Dr. Gary Tucker, Rex Garner, and Brett Perrett, Arkansas Tech University, for technical assistance.

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A BIBLIOGRAPHIC SUMMARY OF ARKANSAS FIELD BOTANY

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ABSTRACT

Over 750 references, compiled over the past five years, are presented on floristics, taxonomy, autecology, synecology, species biology, habitat analysis, impact analysis, paleoenvironment, phytogeography, and history of field botany in Arkansas. This bibliography is reported to facilitate efforts to document and interpret the flora, the vegetation, and the natural heritage of Arkansas and to encourage others to participate in that collective effort.

INTRODUCTION

Arkansas has a flora and vegetation that is characterized by richness and diversity, reflecting its location in the Mid-South, its varied and rugged topography, and the uninterrupted occupation of habitats during the Pleistocene and Holocene. Efforts to describe, inventory, and interpret the flora and vegetation have resulted in the compilation of an imposing body of literature. Access to plant literature was made difficult by the lack of a recent and relatively comprehensive bibliographic compilation. The last bibliography was prepared by Dale (1963) who added 102 references of vegetation studies to an earlier list of 63 taxonomic papers reported by Buchholz and Palmer (1926). According to our list, approximately 60% of the literature documenting or interpreting field botany in Arkansas was reported after 1963. Much of this recent literature is in the form of status reports, government documents, agency reports, and contract reports. In contrast to references in standard journals, this newer body of knowledge is deposited rather than disseminated, abstracted, and widely circulated, and thus, it is less well known and is cited infrequently.

The problem of access to an ever increasing body of literature on field botany is not a problem restricted to Arkansas. Increased efforts to organize natural heritage information resulted in the preparation of bibliographies on plant studies at the national, regional, and state level. On the national level, Gunn (1956) provided access to the major works on each state flora. On the regional level, Duncan (1953), Egler (1961) and Wood (1983) provided access to the regional literature of the southeastern United States. Summaries of literature for other states in the Mid-south and Northcentral United States have also been prepared and reported: Illinois (Risser, 1984), Iowa (Eilers, 1975; Peck and Roosa, 1983; Peck and Smart, 1985; Roosa and Peck, 1986), Kentucky (Brownie, 1965; Davies, 1953; Fuller, 1979), Louisiana (Ewan, 1967; MacRoberts, 1984; Sundell, 1983), Missouri (Dwyer, 1970; Weher and Ravelie, 1986), and Tennessee (Andre, 1971; Bates, 1985; Corgan, 1977). Workers in these states found that when access to the literature of their state and that of adjacent states is conveniently summarized, interpretations of flora and vegetation problems common to their region are much easier to compare and to assess properly.

Consequently, we prepared this bibliographic summary of 766 references to Arkansas field botanical literature for four reasons: to compile a comprehensive bibliography, to facilitate access to those literature resources, to communicate within and outside Arkansas, and to enhance or stimulate future studies on field botany projects in Arkansas. We welcome notification of references we overlooked and information of new reports, in that we intend to keep the list current, and report update lists as needed.

METHODS

The bibliography includes references cited by Buchholz and Palmer (1926) and Dale (1963) to provide a complete listing. However, as the scope of our search was broader than those two earlier compilations, we also added references reported before 1963. We included any reference on the flora of vegetation of Arkansas, including pertinent information of plant taxonomy, plant ecology (autecology and synecology), floristics, phytogeography, palynology, dendrochronology, vegetation management, status reports on rare species, environmental impact statements of significant tracts of natural heritage value, and literature essential to the proper interpretation of Arkansas' botanical natural heritage, such as general works on soil, climate, and geography or on the history of the exploration and study of the natural resources of Arkansas by early naturalists. Some studies conducted outside Arkansas are included if they are of particular importance to the proper interpretation of Arkansas' natural heritage, particularly if these works were excluded included in recent discussions. References that primarily discuss phytoplankton, agronomic crops, weed control, pest management, or tree plantations were excluded. Rather than cite each soil survey for the 75 counties, a general reference to their existence was noted to direct the reader to the government documents section of the library. Similarly, over 100 reports on the generic flora of the southeastern United States were recently indexed (Wood, 1983), and only a few of these were included. Monographic works on wide ranging taxa were generally not included unless Arkansas material was particularly rare and of national importance. General monographs that include Arkansas taxa are well enough summarized by Smith (1968).

Eventually, any list becomes a matter of personal choice; we included any paper which we deemed to contain sufficient merit that its exclusion might be criticized. Early drafts of the list was submitted for comment to Drs. Ed Dale and Ed Smith, University of Arkansas; Dr. Leon Richards, Arkansas State University; Dr. Gary Tucker, Arkansas Tech University; Dr. Eric Sundell, University of Arkansas at Monticello; Drs. Donald Culwell and Robert Wright, University of Central Arkansas; Dr. Henry Robison, Southern Arkansas University; and to Thomas Foti, Steve Orzell, William Shepherd, and Kenneth Smith, Arkansas Natural Heritage Commission. Their contributions added measureably to our list. Several students helped to clerically update the list, including Mark Schweder, Deborah Prince, and Katie Golden.

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ABSTRACT

A study of the distribution, abundance, status, and phytogeography of the six taxa of Log Ferns (Dryopteris: Woodsiaceae) that are known to occur in Arkansas was conducted from 1981-1986. Five of these ferns are generally quite rare in Arkansas. Except for D. marginalis, all exist in Arkansas as small, peripheral populations that are marginal, outlier populations to the west and south or west and north of their metapopulations. Two sterile, triploid hybrid taxa (D. x australis and D. x laevis) each occur at only one locality, and there with but one of their parent taxa. The population of the putatively sterile hybrid D. x australis has a large number of juvenile plants that were not asexually produced by rhizome expansion. The microhabitat of D. x australis is suggested to favor gametophyte establishment. It is speculated that some level of pseudomictic spore production and/or apogamy may be involved in the production of numerous juvenile sporophytes.

INTRODUCTION

The ferns in the homosporous fern genus Dryopteris, commonly known as Wood Ferns, Shield Ferns, and Log Ferns, are conspicuous in eastern North America, are well collected, and well studied ferns that occur on outcrops, forests, and swamps (Carlson and Wagner, 1982; Montgomery, 1982; Montgomery and Paulson, 1981; Small, 1938). The plants are medium to large in size. Fronds are wintergreen, 2-3 times pinnate, 0.5-2 m in length, with one to eight fronds per plant. Generally no more than one-half of the fronds of a plant are sporiferous. The frond petiole contains 3-6 vascular traces. The indusium is reniform; spores are bilateral, saccate, and 30-60 micrometers in longest axis. Of the 36 taxa in the genus, two-thirds are hybrids. Although the basic species are distinct, hybrids plants are generally indistinct, intermediate, and thoroughly baffling to the non-specialist taxonomist (Dowell, 1908; Tryon and Britton, 1966); therefore, they are collected out of proportion to their occurrence and abundance (Wagner, 1971). Although the occurrence of the hybrids initially rendered the taxonomy of the genus to a level near chaos, it offered unusually rewarding opportunities for biosystematic study in the 1950s-1970s, when relative nomenclatural stability was reached (Lellinger, 1984).

The 15 sexual taxa in North America include nine diploids and six polyploid taxa (Carlson and Wagner, 1982). The taxa display a diverse array of distributional patterns, primarily temperate, boreal, and arctic affinities. Vicarious affinities suggest that the major source of North American diversity was perhaps eastern Asia, with high latitude migration during the Tertiary or during interglacial periods during the Pleistocene. Pleistocene glaciation may have played a major role in the origins of the polyploid taxa by creating conditions that brought sexual taxa together, and thus, facilitating hybridization. Whenever in close proximity, hybridization frequently results in the production of plants of hybrid origin (Carlson, 1979; Tryon, 1986). The hybrids are readily distinguished in the field by 1) comparison of frond morphology which is typically intermediate, 2) by their general rarity of plants to the more abundant “typical” form of plants at that locality, and in the laboratory, 3) by recognition of abortive spores that vary in size and shape of the hybrids compared to the uniform size and shape of spores of the “typical” plants.

The 13 northern sexual taxa are known to form 29 different hybrids out of a possible 78. These hybrids plants often are quite persistent and may in fact out number the plants of their parental sexual taxa in some locations (Carlson, 1979). Consequently, the ecologic staying power of the hybrids may in fact exceed that of the parent sexual taxa, resulting in populations of hybrid plants where one or both parent taxa are no longer present, a condition referred to as “hybridization by remote control” by Wagner (1943). The relative abundance of hybrids, their intermediate morphology, the extent of inter-connectedness of the hybrids (sharip genomes of 1-4 sexual taxa) have resulted in an extensive literature reporting on the floristics and taxonomic status of Dryopteris in the state, regional, and national literatures.

Studies that have aided appreciably in our understanding of the genus include comparative foliar morphology (Wagner, 1971), gametophyte ecology (Cousens, 1975; Cousens and Hornor, 1970), spore morphology (Barrington et al., 1986; Crane, 1953, 1955, 1956, 1960; Reed, 1954; Whittier and Wagner, 1971), spore abortion (Wagner and Chen, 1965; Wagner et al., 1986), cytology (Hickok and Klekowski, 1973; Manton and Walker, 1953; Walker, 1969; Wagner, 1971), flavinoid chemistry (Scora and Wagner, 1954; Widen et al., 1975), and more recently, electrophoresis of foliar proteins (Euw et al., 1980; Gastony, 1986). The systematic research has led to the postulation of a number of comprehensive theories on the reticulation of diploid, triploid, tetraploid, pentaploid, and hexaploid cytomorphic species into a genus-wide complex species involving repeated events of hybridization and polyploidy (Loris, 1977; Wagner, 1980). Taxonomic and systematic efforts are currently aimed at relating North American taxa with those taxa in the east in Europe and to the west in Japan and China. Ecologic efforts must address the character of the local population and those environmental conditions or events which favor hybridization, polyploidy, and must address the means by which sterile hybrid plants out-number sexual taxa in the local population (Carlson, 1979; Nickrent et al., 1978; Wagner and Whitmire, 1957).

Six taxa in the genus Dryopteris occur in Arkansas. Taylor and Demaree (1979) and Taylor (1984) reported four taxa, including three sexual species and one sterile hybrid. Field study by the authors and by others resulted in the addition of one sexual species and one sterile hybrid taxa to the flora, the location of additional populations of the rarer taxa, and a clearer depiction of the distribution of the genus in Arkansas (Peck and Peck, 1986; Peck et al., 1987a, b). The existence of Dryopteris as generally rare, local, and disjunct in Arkansas is a condition similar to that found for Dryopteris in other southern states (Small, 1938). In that the genus Dryopteris in Arkansas occurs primarily as a series of small, local, isolated populations, peripheral to or disjunct from the metropolis of the taxa to the east in the southern and northern Appalachians, the field status of plants and populations of Arkansas Dryopteris was surveyed and inventoried to summarize our current knowledge of their distribution, abundance, and status in Arkansas.

MATERIALS AND METHODS

Herbarium specimens were inspected to complete the survey initiated by W. C. Taylor. Field search was conducted to relocate known populations of rarer taxa and to locate additional populations. Field census
was conducted on populations of each taxa by census of all plants within a 10 m sq plot, a size that circumscribed all plants of all populations of the rare taxa. For more abundant taxa, sample plots of the same dimensions were established. A plant was defined as a shoot apex; excavation was conducted to determine whether vegetative expansion of plants into colonies was evident for selected plants in close proximity. Plants were scored as fertile (sporiferous) adults, sterile adults, and juvenile sporophytes. Spores were collected for subsequent study. A literature review was conducted to interpret phytogeographic relations of Arkansas taxa and to compare them with taxa in neighboring states and the southeastern United States.

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Ploidy</th>
<th>Genome</th>
<th>U.S.</th>
<th>Code</th>
<th>Range</th>
<th>Habitat</th>
<th>1 Co. Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>goldiana</em></td>
<td>2n</td>
<td>G6</td>
<td>NEUS</td>
<td>mississippi, rocky woods</td>
<td>0 not known</td>
<td>ARX.</td>
<td></td>
</tr>
<tr>
<td><em>ludoviciana</em></td>
<td>2n</td>
<td>LL</td>
<td>SEUS</td>
<td>swamp</td>
<td>1</td>
<td>one locality</td>
<td></td>
</tr>
<tr>
<td><em>marginalis</em></td>
<td>2n</td>
<td>NM</td>
<td>NEUS</td>
<td>xeric, rocky woods</td>
<td>1 frequent &amp; abundant</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>celsa</em></td>
<td>4n</td>
<td>GOLL</td>
<td>SEUS</td>
<td>mesic</td>
<td>2</td>
<td>two localities</td>
<td></td>
</tr>
<tr>
<td><em>australis</em></td>
<td>3n</td>
<td>GLL</td>
<td>SEUS</td>
<td>acid, wooded seeps</td>
<td>4</td>
<td>ten localities</td>
<td></td>
</tr>
<tr>
<td><em>ledebourii</em></td>
<td>3n</td>
<td>GL</td>
<td>SEUS</td>
<td>mesic, rocky woods</td>
<td>1</td>
<td>one locality</td>
<td></td>
</tr>
</tbody>
</table>

RESULTS AND DISCUSSION

Results are presented in summary tables with biosystematic, habitat, and phytogeographic data in Table 1 and census data in Table 2.

**Dryopteris carthusiana** (Villars) H. P. Fuchs

The Spinulose Woodfern (Table 1), known earlier as *Dryopteris spinulosa* (O. F. Muell.) Watt, is a circumboreal, amphiatlantic plant that is an allotetraploid (4n = 164) denoted by the genome code IISS (Manton and Walker, 1953). It reaches its southwestern periphery of its range in Arkansas. Although found in swampy woods and moist wooded slopes in eastern North America, it is restricted in habitat in Arkansas, being found at one locality in each of two counties in Arkansas (Peck, 1986a, 1986b). This taxa occurs in Arkansas with not much more than two dozen plants (Table 2). This taxa may be at considerable risk in Arkansas (Table 2) in that few juveniles were recorded. Approximately three out of five plants are sporiferous, but no evidence of currently successful reproduction was noted.

**Dryopteris celsa** (Palmer) Small

The Log Fern (Table 1) is a North American endemic that is an allotetraploid (4n = 164) denoted the genome GOLL (Walker, 1959, 1962, 1969; Britton, 1972). The epithet means “elevated”, referring to the habit of the plant to occur on nurse logs in swamps and seeps. The parents of this taxon are two sexual diploids (*D. goldiana* × *D. ludoviciana*). The ranges of these taxa do not overlap today; it seems likely that during Pleistocene glaciation plant migration, the two ranges combined and hybrids were formed. The sterile, diploid hybrids (genotype code GL) underwent polyploid to become the present day fertile taxon on GOLL. Today *D. celsa* occupies a range latitudinally and altitudinally intermediate between its parents (Wagner, 1972). It occurs from New Jersey (Montgomery, 1975) to its southwestern periphery in Arkansas, Louisiana (Thomas et al., 1973), and Texas, being rare, infrequent, and discontinuous across that range (Wagner, 1972). A completely disjunct segment of the range occurs in the Great Lakes region of Michigan (Wagner et al., 1969) and New York (Wagner and Wagner, 1965).

The Texas population has long been misnamed as *Dryopteris cristata* (L.) Gray (Correll, 1955; Correll and Johnson, 1970; Correll, 1972; Correll and Correll, 1972). There is occurs in Bowie Co. at the margin of a bog near Texarkana, where it was collected on 27 Oct 1925 by E. J. Palmer (29404, MO, GH) and misnamed. The Texas plant is *D. celsa*.

**Table 2. Census data from 10 m sq plots established within 25 populations of Log Ferns (Dryopteris).**

<table>
<thead>
<tr>
<th>Taxon</th>
<th>County</th>
<th>Plots</th>
<th>Apices</th>
<th>Juvenile</th>
<th>Nonfertile</th>
<th>Fertile</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>n</td>
<td>Plot</td>
<td>Apices/</td>
<td>Adults</td>
<td></td>
</tr>
<tr>
<td><em>goldiana</em></td>
<td></td>
<td>4</td>
<td>28</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><em>ludoviciana</em></td>
<td></td>
<td>2</td>
<td>35</td>
<td>31</td>
<td>89</td>
<td>0</td>
</tr>
<tr>
<td><em>marginalis</em></td>
<td></td>
<td>1</td>
<td>28</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><em>celsa</em></td>
<td></td>
<td>4</td>
<td>27</td>
<td>15</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><em>australis</em></td>
<td></td>
<td>7</td>
<td>15</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><em>ledebourii</em></td>
<td></td>
<td>3</td>
<td>31</td>
<td>3</td>
<td>13</td>
<td>0</td>
</tr>
</tbody>
</table>

**D. cristata** is found north of the unglaciated region, and has been excluded from the southeastern United States (Thomas, Wagner, and Mesler, 1973).

In Arkansas, *D. celsa* was discovered 24 May 1925 by B. C. Marshall (9, US) at York Springs, located south of Imboden, Lawrence Co.; specimens were sent to W. Maxon, who correctly identified the plant. That population is now extirpated, with the area being heavily pastured; the spring marker now acts as a cenotaph marking the location. It was subsequently located at four populations in Polk County (Moore, McWilliams, Ilits 52040, US, MO; Peck 84705, LRU, MICH, MIL), two populations in Montgomery Co. (Peck 84703, LRU, MIL, MICH), and one population in Garland Co. (Peck 84680, LRU, MICH, MIL). At none of the extant populations are either parental species present. *D. goldiana* is not known from Arkansas, occurring to the north of Arkansas in Iowa and Missouri (Iffrig, 1979); its genes are present in Arkansas only as an expression of its derived hybrid taxa *D. celsa*. The other parental taxa, *D. ludoviciana* does not occur in Arkansas, but is geographically separated from *D. celsa*.

This taxa occurs as small populations (Table 2), without juveniles, but with most plants sporiferous. Although conditions are generally good for gametophyte growth, based on the generally moist substrate, no indication of gametophyte establishment or sporophyte recruitment was noted. These populations are thus ecologically fragile.

**Dryopteris ludoviciana** (Kunze) Small

The Louisiana Log Fern (Table 1) is a fertile, sexual diploid (2n = 82) denoted by genome LL (Walker, 1959). Geographically, it is a North American endemic. Its epithet refers to its initial discovery in Louisiana, although the plant is clearly more abundant in Florida, from where it was renamed erroneously as *D. floridanaum*. The plant frequents swamps and damp woods on the Atlantic Coastal Plain and Gulf Coastal Plain of the Southeastern United States. It was recently located in Arkansas (Sundell & McIntyre 2864, UAM; Peck & Peck 84641, LRU, MICH, MIL). The Arkansas population is the fourth located west of the Mississippi River (Peck et al., 1985; Peck et al., 1985); the three other populations are 350 km disjunct from the Arkansas population in...
Distribution, Abundance, Status, and Phytogeography of Log Ferns (Dryopteris: Woodsiaiceae) in Arkansas

Bradley Co., being found earlier in Louisiana (one population) and Texas (two populations). The Arkansas population is the most northwestern population of this taxon. This taxon differs in population structure from other fertile species of Dryopteris in Arkansas. Juvenile sporophytes were found (Table 2); however, few sporophytes plants are sporiferous. Substrate conditions are generally favorable for gametophyte establishment. Although vegetative expansion is likely, no evidence of connections among plants could be found. It thus seems likely that sexual reproduction of this taxa occurs in Arkansas, but that it is more successful in producing plants that live long enough to reach reproductive maturity. Conditions for this plant may be close to its tolerance limits, but may not be limiting reproductive phenomena. Drought conditions or cold weather may hinder the survival of sporophytes more than the successful maturation from spore to gametophyte to sporophyte.

Dryopteris marginalis (L.) A. Gray

The Marginal Shield Fern (Table 1) is a sterile, sexual diploid (2n = 82), denoted by genome code MM (Manton and Walker, 1953). It is a North American endemic that frequents rocky, wooded slopes and ravines. It occurs in 34 counties in the northwestern one-half of Arkansas in the Ozark and Ouachita mountains. It is the only widespread and abundant Dryopteris in Arkansas. Population of this taxa (Table 2) are often quite extensive, consisting of hundreds of plants, most of which are fertile, but consist of surprisingly few juvenile plants. It is not clear why this plant is so much more widely distributed and locally abundant than the other plants based on reproductive structure of its populations. Although its habitat is abundant, conditions on dry rocks can hardly be thought of as being highly conducive to reproduction. Characterization of the microhabitat which does lead to successful establishment of new plants might well be very informative to the reproductive biology of this genus.

Dryopteris x australis (Wherry) Small

The Southern Wood Fern (Table 1) is a sterile hybrid, being a triploid (3n = 82 + 41) denoted by the genome code L.L.G. It is the backcross hybrid (Wagner and Musselman, 1982; Walker, 1962) between the fertile allotetraploid D. celsa (LLGG) and the fertile diploid D. ludoviciana (LL). D. x australis, first discovered in 1927 in Alabama (Small, 1938; Wherry, 1937, 1961), is a North American endemic that occurs across the southeastern United States. The Arkansas population was the eighth known in North America; Arkansas was the fifth state known to have this taxa: North Carolina (two populations), South Carolina (one population), Alabama (two populations), and Louisiana (two populations). Both Louisiana populations are now extripated; the Arkansas population, the third located west of the Mississippi River, is now the only extant population west of the Mississippi River. Since its discovery in Arkansas, one population each was located in Georgia, Tennessee, Virginia, and Mississippi (pers. comm., W. Wagner and C. Werth, 1988). In Arkansas, it occurs in Garland Co. (Orzell 1429, UARK; Peck & Peck 84880, BLY, MICH, MIL). The Arkansas population co-occurs with one parental taxa, D. celsa (Orzell and Peck, 1985; Peck et al., 1985), with the other parental taxa (D. ludoviciana) not present in Arkansas except 200 km distant in Bradley Co. The nearest population of D. x australis occurred 50 km to the south in Louisiana; presently, the nearest extant population occurs 500 km to the southeast in Mississippi.

The population structure of this taxa in Arkansas is quite unexpected (Table 2). Far more juvenile plants were found at one population of this "sterile" hybrid than for all populations of all fertile species combined. The local substrate was moist, but it was equally moist at locations where D. celsa occurred, but where juveniles were not encountered. These juveniles were not produced by vegetative expansion from existing plants; connections were not encountered. Some plants were small and appeared to have gametophyte tissue attached. It seems reasonable to speculate that these plants may have originated from spore production that in some way was not "sterile", possibly by pseudomictic reduction (De Benedictus, 1969; Morzenti, 1962; Whittier, 1970), producing good spores, and apogamy of gametophytes to produce sporophyte plants. Alternatively, they may represent arrested develop-

ment of plants that initiated colonization at the time of the successful adult plants, but have been held back by unknown genetic, phylologic, or developmental phenomena. This requires additional study to clarify whether either of these alternative explanations is sufficient and valid for this population.

Dryopteris x leedsi Wherry

Leeds' Wood Fern (Table 1) is a sterile triploid (3n = 41 + 41) hybrid taxon endemic to Arkansas. Its genome code is GLM. It is the backcross hybrid (Wagner and Wagner 1965, 1966; Walker, 1962) between the fertile allotetraploid D. celsa (GGLL) and the fertile diploid D. marginalis (MM). It frequents steep, rocky, wooded slopes, seeps, and swamps. Significantly, the Arkansas population was the first discovered, and was designated the type locality of the taxon (Wagner and Taylor, 1976). Six populations are now known from four states in North America: Arkansas (one population), Maryland (two populations), and Pennsylvania (one population). Its distribution is sympatric with its parental taxa, being distributed along the interior highlands of southeastern United States.

In Arkansas, it occurs in Van Buren Co. (Palmer 33216, NY, US; Demaree 10039, US; Moore 350441, NY, US; Taylor 2597; SIU; Wagner & Wagner 74164, MICH; Redfearn 29403, SM; Peck & Peck 84721, IRL, MICH, MIL) at a moist, rocky, wooded slope where only one (D. marginalis) of its two parental taxa occurs. It was discovered by E. J. Palmer on 30 Mar 1928; its taxonomic status was problematic, being often called the "Palmer" Dryopteris. The plants were inspecked by Demaree in 1932, and D. Moore, in 1935. The importance of the plant was realized in the early 1960s, but it could not be relocated. An extensive search of its type locality in 1972 by Taylor and Demaree revealed that it has been recorded by Wagner and Taylor, 1976; Taylor, 1982). This hybrid has occupied the same location for over 60 years; it is over 600 km disjunct from its nearest population. Based on discussions with Demaree, Taylor, and Wagner, the present status of the population is unchanged, or a few apices less than when first discovered (Table 2). Juveniles were never seen; from limited inspection, the plants appear to have a connection, suggesting that the population is the vegetative expansion of one plant.

CONCLUSIONS

The wood fern genus Dryopteris is represented in Arkansas by plants that have limited capacity to quickly replace themselves. Consequently, the long-term persistence of plants is extremely important to the continued success of that population. Populations of the fertile, sexual species generally did not have juvenile sporophytes present: only D. ludoviciana had juveniles, and that population was characterized by having the fewest number of fertile sporophytes, suggesting that adult survivorship is limited. Based on these observations, all collectors should take great care never to collect entire plants of this fern. One fern is sufficient to obtain a confirmation of its identity and voucher its presence by deposition in an herbarium. It is quite important to continue to search for and document any new populations of this genus in Arkansas. Arkansas populations are peripheral to the range of all of these taxa, and provide outstanding opportunities to conduct studies of local population dynamics of these ferns.

The population structure of the "sterile" triploid hybrid D. x australis is astounding. It consists of very large fertile adults surrounded by a large number of immature, juvenile sporophytes. The moist conditions of the seepage area certainly would enhance the opportunity for any good spores of this sterile taxa to have a chance to establish a gametophyte and produce a sporophyte. The moist conditions would enhance gamete transfer, and certainly would not hinder apogamy. It is possible that pseudomictic reproduction occurred and that unreduced spore mother cells developed into giant spores, and gave rise to gametophytes and sporophytes. The genetic constitution of these juveniles is intriguing, as to their prolific level and the identity of the genomes that they carry. Alternatively, the juveniles might be as old as the adult plants, but are suppressed in development by unidentified factors. The alternative that the juveniles represent vegetative expan-
sions from the adults was ruled out by excavation. Additional study is essential to ascertain the ecologic and reproductive events which led to this peculiar structure of a population of a sterile hybrid.

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LITERATURE CITED


Distribution, Abundance, Status, and Phytogeography of Log Ferns (Dryopteris: Woodsiaceae) in Arkansas


DISTRIBUTION AND STATUS OF THE BRAZILIAN FREE-TAILED BAT (TADARIDA BRASILIENSIS CYNOCHEPHA) IN ARKANSAS

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ABSTRACT

Investigations of building infestations, mist netting activities, and specimens submitted to the Arkansas Department of Health document the Brazilian free-tailed bat to be found in 14 Arkansas counties. Both overwintering and maternity colonies were examined. Numbers of individuals ranged from one to several thousand.

INTRODUCTION

Until 1982, the known Arkansas range of the Brazilian free-tailed bat (Molossidae: Tadarida brasiliensis cynocephala) was limited to Ashley, Hempstead, and Pulaski counties where individual specimens were found roosting solitarily or in colonies of the evening bat, Nycticeius humeralis (Sealander, 1979; Sealander and Price, 1964). Saugey et al. (1983) reported the first known occurrences of maternity colonies, added two new county records extending the northern distribution approximately 40 km, and firmly established the Brazilian free-tailed bat as an Arkansas resident mammal. Steward et al. (1986) reported the occurrence of the bat from seven additional southwestern Arkansas counties, and Saugey et al. (1988) reported the capture of seven Tadarida while investigating the bat fauna of Hot Springs National Park in Garland County.

Heidt et al. (1987), reporting on bat rabies in Arkansas, indicated the exact range and status of this bat in Arkansas was unknown. The purpose of this paper is to present the known distribution and status of the Brazilian free-tailed bat in Arkansas.

METHODS AND MATERIALS

Data for this study were derived from specimens submitted to the Arkansas Department of Health Rabies Laboratory (ADHRL), investigating infestations of buildings and homes, mist netting pools in perennial streams, and consolidating published literature.

RESULTS AND DISCUSSION

The known distribution of the Brazilian free-tailed bat, Tadarida brasiliensis cynocephala, in Arkansas is shown in Figure 1. Annotations for the 14 counties follow:

ASHLEY COUNTY: Two free-tailed bats were captured in June and May, 1960 and 1961, respectively, from an attic of a residence in Crossett. Both animals were found in a small maternity colony of evening bats (Sealander and Price, 1964).

CLARK COUNTY: Seven individuals have been submitted to the ADHRL. On 3 March 1983 and 24 March 1984, individual males were submitted, and on 2 April 1984, five females together with four big brown bats, Eptesicus fuscus (two of each sex) were submitted from a single locality. Submissions of these two species from Garland County were recorded during the same time period.

FAULKNER COUNTY: Saugey et al. (1983) reported the occurrence of a large maternity colony in old dormitory building on the campus of Central Baptist College in Conway, and briefly discussed roost characteristics and the significance of this maternity site. Since that date, more data have been collected and will be reported elsewhere. This colony, however, numbered between 1500 and 3000 individuals and used the roost throughout the year. Big brown bats were found in association with the free-tailed bats.

GARLAND COUNTY: The first occurrence of Tadarida in this county was reported by Saugey et al. (1983) when they reported a maternity colony of approximately 100 individuals roosting with a maternity colony of the evening bat. This colony was located in the attic of an old two story apartment building in downtown Hot Springs. Since then, several other colonies have been located in the Hot Springs area, numbering up to 5000 individuals. Between 1983 and 1986, 96 specimens have been tested by the ADHRL, with one animal testing positive for rabies (Heidt et al., 1987). Saugey et al. (1988) captured seven Tadarida (6 males/1 female) in mist nets while conducting a survey of bats in Hot Springs National Park.

HEMPSTEAD COUNTY: Sealander (1979) made reference to a male free-tailed having been collected from an evening bat colony in the city of Hope. Other than this brief reference, however, published data as to time of year, number of specimens removed, and collector are unknown.

HOWARD COUNTY: One male bat was collected from a church steeple in Nashville on 8 May 1986.

LAFAYETTE COUNTY: A number of male specimens were extracted from cracks and crevices in the Highway 313 bridge located 13.5 km southeast of Lewisville on 8 October 1983. This small colony was dispersed throughout suitable areas within the structure of the bridge and was found in association with Eptesicus.

LITTLE RIVER COUNTY: A colony numbering over 600 individuals was observed in an abandoned two story frame house in the community of Winthrop from November, 1984 through June, 1985. Large quantities of guano and many skeletons and decaying bats indicated that this colony had occupied the house for a long period. The house was utilized throughout the year and Eptesicus were found in conjunction with the Tadarida. When revisited in October, 1987, the house was badly deteriorated and had been abandoned by the bats.

LONOKE COUNTY: A single male specimen from the city of Lonoke was submitted to the ADHRL in February, 1984.

MILLER COUNTY: Previously reported by Steward et al. (1986), a single male specimen was submitted to the ADHRL in September, 1983. Since then, a colony of males were discovered roosting in a bridge spanning the Red River. In addition, one male was taken from a house in Texarkana on 19 June 1986.

OUACHITA COUNTY: One male was collected from Camden in July, 1983.

POLK COUNTY: A temporary colony consisting of 14 Tadarida (4 males/10 females) was found roosting with an equal number of Eptesicus during October, 1986 in the main pavilion area of Shady Lake Recreation Area on the Ouachita National Forest. Forest Service personnel indicated that the colony had been much larger in late spring and early summer and had diminished toward autumn. The pavilion was an open structure and heated during winter months rendering it unsuitable for overwintering quarters. Approximately 65 km southwest of the Shady Lake site, Hardisty et al. (1987) found an active colony of free-tailed bats in a building at Beaver’s Bend State Park in southeastern Oklahoma. This was the first record for this subspecies in Oklahoma.

PULASKI COUNTY: Sealander and Price (1964) reported the capture of an adult female in October, 1962. This animal was captured on the University of Arkansas Medical Sciences Campus and represented the first record for the species. A number of colonies as well as individual records have been reported from the Little Rock area since that time. In many instances Eptesicus have been associated with Tadarida.

SEVIER COUNTY: An estimated colony of 1500-2000 individuals was investigated in 1986-87 in the high school gymnasium at Horatio.

DISCUSSION

The data reported in this study demonstrate that Tadarida brasiliensis cynocephalus have become widely distributed in Arkansas. Maternity sites are located in several widespread localities and at least a portion, if not most, of the general population overwinters in the state. Many of the single specimens that have been sent to the ADHRL may actually be indicative of yet undiscovered significant local populations. The species is often found in association with evening and/or big brown bats.

Free-tailed bats apparently utilize a wide variety of structures for roosting sites, as bats were found in bridges and open pavilions in addition to closed buildings (both occupied and unoccupied). In extensive surveys, however, no free-tailed bats have been found in abandoned mines or caves (Heath et al., 1986).

Davis et al. (1962) hypothesized that Tadarida would overwinter only in a favorable building (which they implied should be heated above freezing) and in an area which rarely received frost. Spennath and LaVal (1974) speculated that in reality, food and temperature were probably both limiting factors and that some Tadarida may winter as far north as favorable sites and dependable food supplies are available. Relatively mild winters, the protracted period during the year when plentiful insect prey are available, and the abundance of suitable roost and foraging habitats will probably contribute to the eventual statewide occurrence of this species.

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LITERATURE CITED


THE BATS OF HOT SPRINGS NATIONAL PARK, ARKANSAS

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ABSTRACT
A survey was conducted from June 1982 through January 1987 to determine the occurrence of bat species in Hot Springs National Park, Garland County, Arkansas; an area of approximately 2025 hectares. A total of 309 bats in the families Molossidae and Vespertilionidae were captured. Species represented included: Eptesicus fuscus, Lasiusus borealis, Lasiusus cinereus, Nycticeius humerals, Pipistrellus subflavus, and Tadarida brasiliensis cynocephala.

INTRODUCTION
From June, 1982 through January, 1987 we conducted a survey of bat species occurring in Hot Springs National Park (Garland County), an area of approximately 2025 hectares. Located in the Ouachita Mountains of west-central Arkansas, the park is somewhat unusual in that it partially surrounds and partially lies within the city of Hot Springs. This arrangement provided considerable diversity of potential bat habitat, ranging from occupied to unoccupied man-made structures, relatively undisturbed north slope hardwoods (Quercus/Carya spp.), south slope shortleaf pine (Pinus echinata), and mixed hardwood-pine forest types.

Two perennial streams, Bull Bayou and Gulpha Creek, and a number of ponds, both within and adjacent to the park boundary, provided riparian habitat and foraging sites. Additional habitat was provided by two abandoned mine drifts. One drift occurred within the park boundary near DeSoto Park, a city property. The other drift was located near the city waterworks facilities, north of Hot Springs. These drifts offered the only subterranean, “cave-like” habitat in the immediate area.

Published information concerning the bat fauna known to occur within the park is scarce. Gregg (1937) reported the occurrence of two specimens of the hoary bat (Lasiusus cinereus). Sealander and Polecha (1981) reported specimens of the red bat (Lasiusus borealis), evening bat (Nycticeius humerals), the eastern pipistrelle (Pipistrellus subflavus) and a “flying” sight record for the little brown bat (Myotis lucifugus) and a sight record for the big brown bat (Eptesicus fuscus).

Additional information concerning the occurrence and distribution of bats in the Ouachita Mountains and adjacent to the park, Hot Springs, and Ouachita National Forest have been reported by Davis et al. (1955), Heath et al. (1983, 1986), McDaniel et al. (1986), Saugey et al. (1983), Sealander (1956, 1979), and Sealander and Young (1955).

The purpose of this study was to determine and provide natural history data concerning the bat fauna common to Hot Springs National Park. Furthermore, since the study area is located within the Ouachita Mountains and contains habitat typically found in that physiographic province, the data contained herein should provide important additions to the understanding of chiropteran biology in the Ouachita Mountains.

MATERIALS AND METHODS
Collection was primarily by mist netting as described by Tuttle (1976). A total of 30 net nights (a net night is one mist net opened into the capture position for the evening’s activities) were generated on 18 different dates, with one to three net nights per date. Nets of different lengths (5.5, 12.8, and 18.3 meters) were erected and opened into the capture position prior to dusk and checked at five minute intervals until midnight (occasionally until 0100 hours). Actual netting periods varied from three to six hours depending upon time of year. Netting primarily occurred over shallow pools in Gulpha Creek in the Gulpha Gorge Campground. Each bat was removed from the net and species, sex, age, reproductive condition, time of capture, and ambient temperature were recorded. In addition, two abandoned mine drifts were visited on several occasions during winter months to determine their use as hibernacula. In accordance with National Park Service policy, all individuals were released at the conclusion of the evening’s netting activities.

Assignment of bats into age classes was determined by closure of phalangeal epiphyses. Bats were designated as juveniles on the basis of small overall size, as well as visual observation of incomplete ossification of the epiphyses.

Reproductive condition of males was determined by the position of the epididymis. Scrotal males were characterized by complete descent of the epididymis into pigmented sheaths dorsolateral to the tail and by the presence of enlarged testes. Females bats were diagnosed as pregnant by examination of an obviously enlarged abdomen and lactation was determined on the basis of teat examination.

RESULTS AND DISCUSSION
A total of 309 bats representing two families, five genera, and six species were captured during the study. Two abandoned mine drifts were examined and found to be utilized intermittently by two species.

Family Vespertilionidae

Nycticeius humerals (Rafinesque)

Baker and Ward (1967) considered the evening bat to have been the second most common bat in southeastern Arkansas while Gardner and McDaniel (1978) found this species to be relatively uncommon, but present in small numbers during much of the year in northeastern Arkansas. Heath et al. (1983) reported twelve new county records, including Garland County, and McDaniel et al. (1986) reported on the occurrence and distribution of the species in southwestern Arkansas. During this study, 136 evening bats (74 males and 62 females) representing 44% of all bats captured were netted.

Two pregnant females weighing 12g each were netted on 23 May 1983. The following week (1 June) three pregnant females were netted and ranged in weight from 10.5 to 12.3g. A juvenile male, weighing 6g, was netted on 30 June 1982 and on 1 July, two additional juvenile males, weighing 5g and 6g, were netted along with a postlactating female. On 13 July, four postlactating females were captured. By 26 August, juveniles of both sexes averaged 8g with adults 2-3g heavier.

The average weight of adult males ranged between 8-9g from spring until late August when they began to rapidly gain weight. By late fall, the average adult male weighed 12.3g, an increase of 34%. Adult non-pregnant females gained an average of 29% of their body weight from 9g in spring and summer to a late fall weight of 12.7g. Adult and juvenile males were observed to be scrotal in mid-August with juveniles exhibiting testes as large as the adults. Similar observations were made by Baker and Ward (1967).

An interesting behavior was observed for this species on 11 October 1986, when bats were frequently captured in small groups of three or four individuals. The first group captured was composed of two females and two scrotal males. They struck the net simultaneously in a space...
The Bats of Hot Springs National Park, Arkansas

approximately 0.5 meters in diameter; indicating they had been flying very close to one another. Approximately twenty minutes later a second similarly composed group was captured. Fifteen minutes later two small groups composed of two and three scrotal males were captured when they simultaneously struck the net at opposite ends. The significance of this behavior was probably associated with late summer/early fall swarming activities.

Although common throughout the study, *Nycticeius* were netted in greatest numbers from the last week in August until the second week of October. Baker and Ward (1967) netted this bat in December and indicated the species was most likely a winter resident of southeastern Arkansas. Sealander (1960) reported the occurrence of this bat near Fayetteville (Washington County) in mid-February. The capture of an adult male on 30 January 1987 probably indicates this species, at least in limited numbers, is a winter resident of west-central Arkansas. The sex ratio for all evening bats netted during this study was 54:46, very similar to the 59:41 ratio reported for southeastern Arkansas by Baker and Ward (1967). The relative abundance of this species was probably due to the large number of older homes and buildings in and adjacent to the park. According to Watkins and Shump (1981), most specimens of *Nycticeius* have been found in buildings.

*Lasturus borealis* (Muller).

Ninety-one red bats were captured with males (N = 59) encountered nearly twice as often as females (N = 32). LaVal and LaVal (1979) made similar observations regarding red bats in Missouri. Females were better represented in samples taken in May, June, and July, but were absent or occurred less frequently in samples during late summer and fall. Pregnant females were captured on 15 May 1984 (13.3 g), 22 May 1983 (two weighed 14g each) and 1 June 1983. Lactating females were captured on 30 June and 18 July, 1982 and on 8 July 1983. Two postlactating females were captured on 1 July 1982 and one was captured on 8 July 1983. Volant juveniles were first observed on 30 June 1982 when a very small female weighing 5g was captured. Late October weights for females averaged 12g.

Males were captured on every occasion and were most abundant from mid-July through September. Two males were netted and several other red bats sighted on 30 January 1987 after a brief winter warming period. Males averaged 13.9g in late October.

As reported by Baker and Ward (1976), red bats often landed on and hovered near a pillow case used to retain captured red bats, apparently attracted by calls made from those inside. The only observed mortality involving any bat during the study occurred when a red phase screech owl (*Otus asio*) was captured as it attacked and killed a male red bat that had been netted only seconds before. The owl was released and later flew back down the creek and again became entangled in the net. Predation of bats by this and other species of owls has been well documented and reviewed by Barclay et al. (1982).

*Eptesicus fuscus* (Palisot de Beauvois).

The big brown bat was the third most common species. Sixty-six individuals, 33 males and 33 females were captured. Two pregnant females weighing 21.5g and 23.5g were captured on 23 May 1983, and one pregnant female was captured a week later on 1 June. Lactating females weighing 17g and 20g were netted on 26 June 1982; one of which exhibited worn canines, indicating considerable age. Four days later on 30 June, another lactating female weighing 19g was netted. The first postlactating female was captured one day later on 1 July. The first volant juvenile captured was a 13g female netted on 26 June 1982. Numerous maternity colonies of this species have been located throughout Hot Springs and Garland County. Heath et al. (1986) reported the occurrence of this bat from the abandoned mine drift near DeSoto Park.

Body weight of adult males and females was very similar in late October when the average was 22.5g. Interestingly, juveniles, although nearly as large as adults, weighed considerably less at 15.5 to 17.3g and gave the appearance of having very little body fat. One adult female was captured on 30 January 1987 over a shallow pool in Gulpha Creek.

*Pipistrellus subflavus* (F. Cuvier).

Six eastern pipistrelles were captured during the study. Two lactating females, weighing 4g and 6g, were netted on 30 June 1982, indicating the occurrence of a maternity site nearby. The first volant juvenile was captured two weeks later on 13 July when a 4g male was netted at the same locality. Two early August captures in 1982 and 1983 yielded an average body weight of 5g. Examination of the abandoned mine drift near DeSoto Park revealed limited use during most of the year, with more use in winter.

*Lasiusus cinereus* (Palisot de Beauvois).

The hoary bat was first reported from the park by Gregg (1937) when a large female was found frozen on the exterior door facing of the utilities building on 12 February 1936. The second specimen was recorded on 20 April of the same year when a live animal was captured by a city employee at the Hot Springs pumping plant, approximately 2 miles northwest of the city. Three hoary bats were netted during this study. A large, pregnant female was captured on 1 June 1983; on 26 August, a scrotal male weighing 29g and a large female weighing 26g were netted.

Family Molossidae

*Tadarida brasiliensis cyanocephala* (Le Conte).

Sealander and Price (1964) first reported this species in Arkansas from three widely spaced counties. Sealander and Polechla (1981) did not record free-tailed bats during a small-mammal investigation in the park, but predicted occurrence based on its known Arkansas distribution. Saugey et al. (1983) reported the first known maternity colonies for the species in the state (which included Garland County), expanded the known Arkansas range of the animal, and firmly established this bat as a resident species.

Captures of the free-tailed bats within the park occurred on June 30, 1 July, 26 August, and 23 September of 1982. A total of seven bats (6 males/1 female) were captured with never more than two captured on any evening. Interestingly, the largest known maternity colony of this species ever found in Arkansas (estimated at several thousand individuals) was located approximately 1 air mile away (Saugey et al., 1988). The lack of captures of this species within the park may be attributable to their foraging tactics as described by Kutzsch (1955). He found their foraging routes at various heights, commonly from 5m to treetop level and on occasion, as high as 34m — far above the 2m level of single mist nets. Barbour and Davis (1969) reported *Tadarida brasiliensis mexicana* often traveled great distances, up to 65 kilometers each night, to feed along a river. While the foraging area of the large maternity colony was unknown, one might suspect these bats to have utilized one of the several large reservoirs or the Ouachita River and adjacent forested hills for watering and feeding purposes.

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EGGTOOTH DEVELOPMENT AND MORPHOLOGY IN THE SIX-LINED RACERUNNER, CENNIDOPHORUS SEXLINEATUS (SAURIA: TEIIDAE), USING SCANNING ELECTRON MICROSCOPY

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ABSTRACT

Eggtooth development and morphology in the six-lined racerunner, *Cnemidophorus sexlineatus*, were examined using scanning electron microscopy. The anlage of the embryonic eggtooth emerges from the anterior surface of the palate relatively late during embryonic development. The eggtooth proper erupts through an epithelial sheath and grows anteriorly to project beyond the rostral scale. The mature eggtooth is hollow, has a wall made of enamel and dentine, possesses a sharply-curved body and has a flattened, pointed tip. The eggtooth is shed within several days after the young hatch.

INTRODUCTION

The embryonic eggtooth of squamates (lizards and snakes) is a specialized, deciduous tooth found at the tip of the snout and is attached to the premaxillary bone. It is used to pierce, cut or break through the eggshell (or egg membranes) at the time of hatching or birth (Bellairs, 1970). Squamate eggteeth are similar to their regular teeth, except that they are much larger, are usually one in number (gekkonid lizards may have two) and are curved forward, projecting slightly away from the snout. Chelonia, crocodilians and birds lack a true embryonic egg tooth; however, they do possess a specialized horny, epidermal structure, the egg caruncle, which serves the same function as the eggtooth.

Fioroni (1962) provided the most comprehensive literature survey on the occurrence, structure and development of the reptilian eggtooth. Nearly all references he cited dealt with species outside the continental United States. The few exceptions included three snakes (*Crotalus atrox*, *Nerodia sipedon* and *Sistrurus catenatus*) as reported by Smith et al. (1953). Fioroni (1962) omitted a four snake (*Coluber constrictor*) as investigated by Weinland (1858). The only study describing eggtooth structure in the lizard genus *Cnemidophorus* was by Muller (1841). The present study addresses the chronological changes in lizard eggtooth development and structure in the six-lined racerunner, *Cnemidophorus sexlineatus*, using scanning electron microscopy (SEM). This work is the first to document embryonic eggtooth development for any North American lizard using SEM.

MATERIALS AND METHODS

Eggs of the six-lined racerunner, *Cnemidophorus sexlineatus*, were excavated (see excavation methods in Trauth [1983]) from nests buried in red clay roadside embankments along rural highways in Johnson and Madison counties, Arkansas, in July 1986. Over 100 eggs representing at least 25 egg clutches were collected. Each clutch numbered from one to five eggs, and these clutches yielded embryos in a variety of embryonic stages. In addition, hatching lizards (32-35 mm in snout-vent length) were taken from burrow systems within the nesting habitats. Eggs and hatchlings were fixed in 10% formalin within 24 hr after collection and were later stored in 70% ethanol.

Embryos were dissected from their eggs, placed in separate vials and assigned a descriptive morphological stage following Dufaure and Hubert (1961). These stages, based upon developmental criteria rather than length of incubation time, provided a means of categorizing advancement in embryonic growth. Standard laboratory techniques were used to prepare tissues for SEM. Upper jaws of selected individuals were excised just anterior to the eyes; in more advanced specimens, the eggtooth was extracted with a pair of jeweler’s forceps. All specimens were dehydrated in a graded series of ethanol and amyl acetate, dried with a Samdi critical point dryer, coated with gold/palladium in a Hummer IV sputter coater and viewed with a JEOL 100 CXII TEM-SCAN electron microscope at an accelerating voltage of 40 kV.

RESULTS AND DISCUSSION

Eggtooth development and morphology in *C. sexlineatus* is shown in Fig. 1. The earliest observation of an eggtooth was in an embryo with a crown-to-rump length of 15 mm (Fig. 1A). This size roughly corresponds to Stage 36 in embryonic development (Dufaure and Hubert, 1961) and is characterized by the lack of body pigmentation and by little scale differentiation. At this stage, an anlage of the eggtooth bulges at the anterior terminus of the trabeacula communis (de Beer, 1937). At Stage 37, the rapidly-growing eggtooth pushes from its medial position anteriorly toward the newly-formed rostral scale (Fig. 1B & C). The exposed body of the eggtooth now appears broad, and the lateral surfaces gradually taper to form an apex. The entire eggtooth is covered by an epithelial sheath. A terminal cap (Fig. 1B) is distinguishable from the main body of the eggtooth.

Eruption of the eggtooth proper begins in the region of the terminal cap as evidenced by a sloughing of the epithelium (Fig. 1D). This process exposes the tip of the eggtooth which may exhibit a serrated edge. As the embryo nears hatching (Stage 40), the mature eggtooth has shed most of its epithelial covering (Fig. 1E & I). Its exposed length is a little over twice its width. A rounded and relatively smooth tip was observed in most specimens; however, some specimens exhibited a lancet-like tip (Fig. 1I). In all cases, the eggtooth extends anterior to the rostral scale.

The destruction and subsequent loss of the eggtooth occurs within a few days after hatching (Fig. 1F & G). In Fig. 1F (from a hatching 33 mm in snout-vent length), the eggtooth appears to have been sheared in half. Debris or possibly eggtooth material has accumulated around the remaining stump. Horizontal fracture lines are evident along the base of the stump. The rest of the eggtooth is discarded, perhaps, as hatchlings begin foraging for insects. The ventral edge of the rostral scale (Fig. 1G) will eventually assume a normal shape leaving no trace of the eggtooth.

The morphology of the extracted eggtooth is shown in Fig. 1H & I). The body is oval in cross section and has a hollow central cavity which extends into the flattened tip. The eggtooth wall is relatively thin and consists of two layers approximately equal in thickness. These layers are made of enamel (outer) and dentine (inner). Internally, the lining of the cavity is quite porous, a mat-like network of minute fibers lies on this surface. All mature eggteeth exhibit a curved body. The convex or exposed surface may flare along the lateral edges prior to the tip. Most of the concave surface (normally hidden from view, but evident in H & I) is covered by a thin layer of squamous epithelium.
Early developmental structure of the eggtooth in *C. sexlineatus* is similar to the condition found in a European lacertid lizard (*Lacerta muralis*) as illustrated by Fioroni (1962). In both species the eggtooth eventually curves sharply forward and tapers to a point (as in Fig. 11). These common features are not surprising as these lizards are closely related (Camp, 1923). Although some adult lizards may possess enlarged, medially-positioned premaxillary teeth (amphisbaenids and some agamids), which may or may not be a vestige of eggteeth (Santonja and Bons, 1972; Smith et al., 1953), *C. sexlineatus* completely sheds the eggtooth following hatching. No premaxillary teeth ever replace or fill the gap occupied by the eggtooth.

**LITERATURE CITED**


TOE TIP SURFACE MORPHOLOGY IN SIX SPECIES OF SALAMANDERS, GENUS AMBYSTOMA (CAUDATA: AMBYSTOMATIDAE), FROM ARKANSAS USING SCANNING ELECTRON MICROSCOPY

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ABSTRACT

The toe tip friction surface in six species of Ambystoma (A. annulatum, A. maculatum, A. opacum, A. talpoideum, A. texanum, and A. tigrinum) from Arkansas was examined using scanning electron microscopy. We found no sexual dimorphism in cell surface ultrastructure. Variation within and between species was considerable. The most active burrower, A. tigrinum, possessed the most disorganized cell surface, whereas the least active burrowers (A. annulatum, A. maculatum, and A. opacum) had morphologically similar and relatively smooth toe tips. In A. talpoideum and A. texanum, cell surfaces exhibited micromotions. Only these two species possessed mucous pores in close proximity to the friction surface. The microstructure of cell surfaces transcended species groups in Ambystoma and would not represent a reliable taxonomic tool.

INTRODUCTION

By most general accounts, mole salamanders (genus Ambystoma) of the family Ambystomatidae are regarded as leading a burrowing, subterranean existence most of their lives, surfacing only during the seasonal breeding migrations (Bishop, 1943; Conant, 1975). Studies have shown, however, that the burrowing abilities and behavior in Ambystoma greatly vary among the species examined thus far (Gruberg and Stirling, 1972; Semlitsch, 1983). Like many burrowing toads, terrestrial and some aquatic salamanders possess a thickened, cornified epidermal covering on the friction surface of their toe tips. The epidermal covering is darkly pigmented in some salamander species (Bishop, 1943; Caldwell and Trauth, 1979; Juterbock, 1984). Adults and larvae of ambystomatid salamanders, likewise, exhibit both thickened and/or partially horny digital tips (Duellman and Trueb, 1987; Noble, 1993). In Ambystoma, this feature undoubtedly assists or protects digits during the excavation of underground retreats by adults or allows for the seeking of secluded refugia in ponds by larvae.

In the present study, we examined the toe tips of six species of Ambystoma (A. annulatum, A. maculatum, A. opacum, A. talpoideum, A. texanum, and A. tigrinum) native to Arkansas using scanning electron microscopy. Our primary objectives were to determine: 1) the ultrastructure of the toe tip friction surface, 2) whether interspecific differences in toe tip morphology are related to the burrowing tendencies of these species, and 3) the usefulness of toe tips as a taxonomic tool.

MATERIALS AND METHODS

We examined the toe tip friction surface of adult specimens (N = 43) of six species of Ambystoma (A. annulatum—4 males, 4 females; A. maculatum—4 males, 4 females; A. opacum—4 males, 4 females; A. talpoideum—3 males, 2 females; A. texanum—4 males, 4 females; A. tigrinum—4 males, 2 females) using scanning electron microscopy (SEM). All animals were collected from localities in Arkansas during 1985-87. Individual toes or portions of the entire left hind foot were excised from animals which had been previously killed in a dilute chloretone solution, fixed in 10% formalin, and stored in 70% ethanol. Laboratory techniques used to prepare toes for SEM followed routine procedures (Dawes, 1979) and included dehydration in a series of ethanol with amyl acetate serving as the transition solvent. Samples were dried in a Samdri critical point dryer and coated with gold/palladium in a Hummer IV sputter coater from 2 - 5 min. A JEOL 100 CXII TEM-SCAN electron microscope was used to view toe tips at an accelerating voltage of 20 kV. All specimens and preparations are deposited in the Arkansas State Museum of Zoology.

RESULTS AND DISCUSSION

Toe Tip Surface Morphology

The cornified friction surfaces of the toe tips of the six indigenous species of Ambystoma in Arkansas are shown in Figs. 1 & 2. We found no sexual dimorphism in cell surface ultrastructure. The range of variation within and among species was considerable and possibly indicated degree of wear or age of the epithelium. Toe tip surface topography ranged from very smooth or gently contoured to relatively rough, whereas cell surface ultrastructure was less variable and showed few modifications. For example, A. opacum (Fig. 1A) normally exhibited a smooth squamous epithelium as did A. maculatum; however, one specimen of A. maculatum (Fig. 1B) had a fractured, scuffed tip. Both species possessed a similar surface microstructure on their cells (Fig.
Figure 2. Scanning electron micrographs of the toe tip cells and cell surface ultrastructure in six species of *Ambystoma*. A - C. *A. texanum*; line in A = 35 μm; in B, 12 μm; in C, 1 μm. D & E. *A. maculatum*. Pointer indicates a cell border impression on a cell surface following the sloughing of cells; line in D = 2 μm; in E, 0.5 μm. F. *A. annulatum* (magnification same as E). G. *A. opacum*; line = 1 μm. H. *A. talpoidem*. Notice depression left by sloughed cell (pointer) remains surrounded by well-defined cells; line = 20 μm. I. *A. tigrinum*. A relatively rough area of poorly-defined cells is evident (magnification same as A).

Two species, *A. talpoidem* and *A. texanum*, possessed similar tips in that both showed a gently contoured tip (Fig. 1C & D; Fig. 2A) and identical microprojections on cell surfaces (Fig. 2C & H). Of the other two species, *A. annulatum* (Fig. 2F) had a toe tip surface very similar to *A. opacum* and *A. maculatum*. *A. tigrinum* exhibited the roughest toe surface morphology (Fig. 2I) of all species studied.

Mucous Pores and Sloughing of Cells

Only two species, *A. talpoidem* and *A. texanum*, exhibited mucous pores in areas directly adjacent to the friction surfaces (Fig. 1C & D). No mucous pores were observed on the friction surface. Since mucous pores occur between cells, mucous secretions could possibly be distributed onto the surface of toe tips via the myriad of prominent
intercellular spaces. Much is known about mucous pores, glands, and secretions of the enlarged toe pads of tree-dwelling anurans, especially species of tree frogs (Hyla, Rhacophorus, and other genera; Ernst 1973a, b; Green, 1981; McAllister and Channing, 1983; Welsch et al., 1974). The presence and/or nature of mucous pores and secretions in regions near the digital tips is poorly understood in salamanders.

The shedding or molting of the skin (ecdysis) can occur every 4-5 days in Ambystoma (Ling, 1972). The shedding of individual cells or cell clusters was observed in most species. In A. talpoideum, cells can be lost without causing disruption to contiguous cells (Fig. 1C; magnification in Fig. 2H). The method of sloughing and replacement of cells is illustrated in Fig. 2H. Each epithelial cell bears the impressions of formerly discarded cells, and an overlapping pattern of replacement is apparent.

Burrowing Tendency

Semlitsch (1983) reported on the burrowing activities of five of the six species of Ambystoma in our present study. He found that A. tigrinum always attempted to burrow regardless of the type of experimental substrate, whereas A. talpoideum actively dug only 50% of the time. The other species (A. annulatum, A. maculatum, and A. opacum) were passive burrowers preferring to enlarge crevices or cracks rather than attempt to dig underground.

Our data suggest a casual relationship between burrowing productivity in these species of Ambystoma and the nature of the toe tip morphology; i.e., the greater the tendency to burrow, the more calloused and disrupted the cell friction surface layer. Ambystoma tigrinum whose mostly pointed toe tips are ideal for penetrating substrates had a disorganized toe friction surface. Ambystoma talpoideum (and A. texanum) bears microprojections on cells. These microstructures could aid in locomotion or possibly digging, but their function is unknown. The other three species which prefer to dig possess mostly blunt toes and smooth friction surfaces.

Taxonomic Considerations

According to TiHen (1958), the six species of Ambystoma we investigated belong to four different species groups: mexicanum (A. tigrinum), opacum (A. opacum and A. talpoideum), maculatum (A. maculatum) and subgenus Linguaelapsus (A. annulatum and A. texanum). Because A. annulatum, A. maculatum, and A. opacum have similar cell surface morphologies on toe tips, and, at the same time, are classified in separate taxa, the microstructure of cells of the friction surface is, in all likelihood, a pleomorphic character state and has no bearing on taxonomic affinities within Ambystoma. The similar specialization in design of the cell surface ultrastructure observed in A. talpoideum and A. texanum is noteworthy. Interestingly, some species of Desmognathus, a genus of mostly semi-aquatic, burrowing plethodontid salamanders, also exhibit microprojections on cells of toe tips (Caldwell and Trauth, 1979).

ACKNOWLEDGMENTS

We thank Brian P. Butterfield, Bob Cox, and Walter E. Meshaka for their field assistance.

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COMMENTS ON ESTIMATING POPULATION RATE OF INCREASE FROM AGE FREQUENCY DATA

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ABSTRACT

Although many papers have described assumptions and calculations of \( r \) from different kinds of data, none has compared estimates of \( r \) for the same real data set under different assumptions. We used the age distributions of gray foxes collected during six trapping seasons to estimate and compare \( r \) and \( l_x \) series derived under different assumptions. Because trapped foxes are killed, they are believed by some to represent death history data. We found this treatment underestimates survivorship and leads to erroneous conclusions about the population. Use of a projection matrix allowed prediction of population size and thus allowed us to predict "observed" rate of increase. Use of projection matrices also resulted in the most conservative estimated of \( r \).

INTRODUCTION

Since the early 1960's mammalogists have become increasingly interested in population dynamics. Caughley and Birch (1971) pointed out that many of the estimates of rate of increase (\( r \)) in papers resulting from this interest were inaccurate because "time-specific" data were used. Construction of time-specific life tables is based on the assumptions that 1) the population has a stable age distribution, 2) there is no bias in the data, and 3) \( r = 0 \). Estimation of \( r \) in time-specific analysis approximates zero because the calculation "retrieves an assumption and disguises it as a conclusion" (Caughley and Birch, 1971). Tait and Bunnell (1980) noted that this statement is not true if age-specific probability of survival from birth (\( b_i \)) is estimated from the distribution of ages at death of animals found dead. Still, they concluded that while \( r \) was possible to estimate in theory, it is virtually impossible to estimate in practice. Given these usually untenable assumptions, it might seem that there is no point in attempting to estimate rate of increase from life table data. Michod and Anderson (1980) indicated, however, that by calculating \( r \) and \( l_x \), jointly questions concerning population dynamics, the data, or the validity of the model can be addressed.

Several authors have offered logic for the calculation of population parameters. Leslie (1945; 1948) used matrices to project future age structure and population size. Conley (1978), Downing (1980), Michod and Anderson (1980), Tait and Bunnell (1980), and Lenski and Service (1982) discussed calculation of population parameters from different kinds of data. One approach lacking in these treatments is a comparison of estimates of \( r \) calculated for the same real data set under various assumptions. The purposes of this paper are to estimate and compare \( l_x \) series and \( r \) calculated under different assumptions for trapped samples of gray fox (Urocyon cinereoargenteus).

METHODS AND MATERIALS

Skulls of gray foxes were obtained from furbuyers in Arkansas during six December-January trapping seasons from 1977-78 through 1982-83. Age estimates were made using dental criteria (Tumlison and McDaniel, 1984). Accuracy of age estimates affects the calculated values of population parameters, but this was not considered to be a major source of bias because foxes are among the easiest mammals to age (Matson, 1981). Age structure for each sample is given in Table 1.

Three approaches for the development of an \( l_x \) series were used with these data. A large sample, obtained during year 2 (1978-79), was used to develop a time-specific \( m_x \) series in which \( r \) is usually assumed to be zero. The approach of Leslie (1945) and Michod and Anderson (1980) does not require an assumption of stability, therefore \( r \) was estimated from the single sample using fecundities of the type termed \( F \) (Leslie, 1945) rather than the usual \( m_x \) fecundities.

Because most animal populations are not truly stable, variation in the initial size of the cohorts represented is often reflected in age structure determined from a single sample. Downing (1980) indicated that a composite of several years of census data largely avoids the problem of unequal cohorts. To evaluate the potential difference, another time-specific analysis was made using a composite sample of the 6 years of data. Year 2 contributed significantly to the size of the composite sample, and reduced the differences between \( l_x \) schedules. Again, \( r \) was estimated as described above.

Finally, a dynamic analysis in which stability is not assumed is possible using data from years 2 and 3. During the analysis, the sample size of year 3 was made equal to that of year 2 and proportioned among age classes. By following age class 0 of year 2 to age class 1 of year 3, survival rate for that cohort during sample year 2 was estimated. Survival

<table>
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<tr>
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<th>Trapping Season</th>
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<tr>
<td></td>
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<td>31</td>
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</tr>
<tr>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>6+</td>
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</tr>
</tbody>
</table>

Table 1. Age structure of samples of gray fox taken during December-January trapping seasons in Arkansas. Year 1 was 1977-78, year 6 was 1982-83.
Comments on Estimating Population Rate of Increase From Age Frequency Data

rates for each cohort in the sample were used to construct an \( l_x \) series that did not assume stability.

Each of the above approaches treats the data as a sample of the living. Although trapped foxes were killed, they are usually considered to represent a sample from the living population (Caughley, 1966). However, in some exploited fur-bearing populations trapping may be the major source of mortality. Hence, it might be argued that a trapped sample more accurately reflects a sample of the dying. Each of the 3 \( l_x \) series described above was recalculated with this assumption for comparison. Methods for calculation of \( l_x \) given life or death assumptions were described by Downing (1980).

To calculate \( r \), both \( l_x \) and \( m_x \) are required. No \( m_x \) values were obtained with the fox age data, so \( m_x \) values were estimated. Life tables traditionally are constructed to represent the female portion of the population. Pielou (1977:33) stated that populations with a 1:1 sex ratio and identical age distribution between the sexes do not need to be treated separately. Our data indicated that these assumptions were not violated, therefore the data were pooled and all specimens were treated as females. As a result, calculated \( m_x \) values represented the number of female offspring, Wood (1958) provided \( m_x \) data on gray foxes which Michod and Anderson (1980) later used. Their \( m_x \) values were based on placental scars and embryo counts, and the percentage of foxes not breeding. By using the Leslie matrix, an \( m_x \) schedule was developed for our analysis which is proportional to Wood's (1958) data as given by Michod and Anderson (1980) and which made the age structure for the dynamic sample stable (i.e., \( F_x \) in the Leslie matrix projected the same future age structure and population size as that obtained in the dynamic sample). The dynamic sample was chosen for stabilization merely because it does not assume stability. Because this treatment to derive the schedule caused the dynamic analysis to indicate stability (\( r = 0 \)), the dynamic data may now be used as a heuristic device for comparison of other estimates of \( r \). We expect that all estimates of \( r \) should approximate 0 if assumptions of the particular model are not violated.

The discrete time version of the demographic equation (i.e., the characteristic equation of the Leslie matrix) is

\[
1 = \sum_{x=0}^{\infty} e^{-\lambda x} m_x \lambda^x \tag{1}
\]

(Murray and Garding, 1984). Michod and Anderson (1980), using harvested animals for analysis, gave the equation

\[
1 = \sum_{x=0}^{\infty} \lambda^{-x} \lambda^x m_x = \sum_{x=0}^{\infty} \lambda^{-x} m_x \tag{2}
\]

They incorporated their age equation for the solution of \( \lambda \) the term \( I_{lx} \), representing average survivorship of newborn to their first harvest season. The number of age 0 individuals could then be treated in the first age class after having accounted for the difference between the number of age 0 individuals sampled and mortality between birth and sampling (i.e., they used \( F_x \) data). Their approach allowed simultaneous calculation of \( \lambda \) and \( r \) without any assumption concerning the growth rate. Note: \( r = \ln \lambda \).

**RESULTS AND DISCUSSION**

The \( l_x \) series calculated under each assumption are provided in Table 2. We tested the hypothesis that trapping was the major source of mortality using the G-statistic and a 7x2 contingency test (Sokal and Rohlf, 1969) to compare \( l_x \) series developed under both life and death data assumptions. If trapping is the major source of mortality, the age structure must reflect such a reality. Conversely, treatment as a sample of the living incorporates all forms of mortality into population structure.

Comparison of the one-year and dynamic series were each significantly different (\( P < 0.005 \)) while the composite sample was significant only between the 0.25 and 10. levels. Comparisons of \( l_x \) series may not be meaningful because an error in the frequency of the first age class results in distortion of \( r \) below it in the series (Caughley, 1966). However, values of \( q_x \) are independent of frequencies in younger age classes and may serve as more sensitive measures for comparison. In our analyses, all comparisons between \( q_x \) series, calculated under life and death base assumptions, were highly significant (\( P < 0.005 \)).

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</tr>
</tbody>
</table>

Some statistical problems appeared using life-based assumptions with the 1978-79 sample. Unequal cohort size may have been responsible for the larger size of the 5-year class, but this translates mathematically into a negative \( q_x \) value; a biological impossibility. For the contingency test, we set the value of \( q_x \) for the 5-year class equal to the corresponding value in the contingency table. This procedure removed the contribution of the class to independence and decreased the calculated significance level, but differences were still sufficient for significance. We conclude from these analyses that the trapped sample of foxes does not represent death data, because sources other than harvest mortality affect the population. Harvest data cannot represent a sample of the dying.

Each of the 3 life-based \( l_x \) series were tested in all combinations for independence. Comparison of the 6-year composite and 1-year samples showed significant differences (\( P < 0.05 \)). This observation indicates that yearly fluctuations in Arkansas gray fox populations reduce the predictive usefulness of single samples. The \( l_x \) series of the composite and dynamic samples were also different (\( P < 0.05 \)). While the dynamic treatment does not assume stability, it is based on relatively static data (2 years). A comparison of the 1-year and dynamic series was highly significant (\( P < 0.005 \)). The greater significance level is probably due to variation from each of these latter series being absorbed in the composite sample, making comparison with the composite series relatively less significant. All comparisons of corresponding \( q_x \) series were highly significant (\( P < 0.05 \)).

As mentioned earlier, the dynamic \( l_x \) series was used to develop a \( m_x \) series that would stabilize that age structure, thus we expect \( r = 0 \).

Rate of increase was calculated by Eq. 1 to be 0.002. Our treatment to develop a \( l_x \) series necessarily set \( b_0 = 1 \), thus rate of increase estimated by Eq. 2 was 0.005.

The Leslie matrix projects future population characteristics assuming constant survivorship and fecundity schedules. By projecting next year's population size based on our sample and observing differences between this estimate and our sample size, an estimate of \( r \) (in this case, observed rate of increase) can be obtained. For our "stabilized dynamic" sample this value was 0.003. We have shown that, given some rounding error, \( r = 0 \) for the dynamic data using our derived fecundity schedule.

Equation 1 cannot be applied to the composite or one-year samples because the \( l_x \) series for these samples are based on the assumption of stability. Equation 2 or Leslie matrices may be used, however. Rate of increase estimated by Eq. 2 for the composite sample indicated a decline (\( r = -0.029 \)) as did the one-year sample (\( r = -0.020 \)). Observed \( r \) estimated by projecting the population for next year via the Leslie matrix also predicted declines (\( r = -0.017 \) and \( -0.012 \), respectively). Estimates of \( r \) by Eq. 2 compared to those derived from Leslie projections were appreciably different. We used the age structure represented by the \( l_x \) series as the column vector multiplicant of the Leslie matrix. Solution of Eq. 2 or calculation of the first position in the projected age structure estimates the agreement between recruitment and the
characteristic value of the first age class of the \( t \) series (i.e., 1.000). For example, if there are 1000 individuals in the first age class at time \( t \), Eq. 2 predicts the number expected to be present at time \( t+1 \). If \( \lambda = 0.971 (r = -0.029) \), recruitment is 971 individuals, which does not replace the age class. The value of \( r \) indicates a loss of 29 individuals from the age class at \( t+1 \). Notice that this is a change of 29 per 1000. Since observed rate of increase is based on change in numbers between \( t \) and \( t+1 \), we sum both the sample and projected \( t \) series to simulate our "population" sizes. For the above example the sums at \( t \) and \( t+1 \) were 1732 and 1703, respectively. This still represents a loss of 29 individuals, but it is now 29 per 1732. Now, \( \lambda = 0.983 \) and \( r = -0.017 \).

The hypothesis that the data represent death history was refuted earlier. To examine the effect of erroneously accepting that hypothesis, \( r \) was estimated by Eq. 2 and by the change in the projected population size. These estimates were, respectively: 0.133, 0.076 (dynamic); 0.030, 0.017 (composite), and 0.213, 0.123 (one-year). Because treatment of the data as death history underestimates mortality, survivorship \( j \) is overestimated; consequently, \( r \) appears more favorable. This type of treatment would lead to a more positive, but invalid, conclusion about the population.

**CONCLUSIONS**

The method one uses to estimate \( r \) depends on the kinds of data available for analysis. Although Eqs. 1 and 2 are mathematically identical, the data required for solution are different. Equation 1 can be used only if an \( l \) series can be obtained that does not assume stability. Since many data sets are based on single samples and Eq. 2 makes no assumptions concerning the growth rate, it has greater utility. Further, it allows the simultaneous calculation of \( r \) and an \( l \) series that accounts for population changes. However, it requires extra effort to obtain \( l \). As Michod and Anderson (1980) point out, "... it may be more reasonable to assume some value for \( l \), rather than assume \( \lambda = 1 \), or \( r = 0 \), as is often done." Investigators should note, if they choose to use Eq. 2, that \( r \) deals with changes in recruitment into the first age class, whereas observed \( r \) deals with changes in recruitment into the population. Because of larger sample size, observed \( r \) is the more conservative estimate. If we continue to use the \( l \) series to represent the age structure of the population, "observed" \( r \) based on matrix projections will always provide the more conservative estimate of \( r \).

**ACKNOWLEDGMENTS**

This project was funded by the Arkansas Game and Fish Commission through Pittman-Robertson funds made available by the U. S. Fish and Wildlife Service. We thank Lew Johnston, Mike Cartwright, and Barry McArdle for providing data, skulls from foxes, and other support. J. H. Shaw and S. E. Trauth offered helpful suggestions concerning the manuscript.

**LITERATURE CITED**


SEX RATIOS IN BOBCAT POPULATIONS

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ABSTRACT
 Reported sex ratios in bobcat populations have suggested great variation ranging from strong male bias to strong female bias. Explanations offered for these observations have included factors of mobility, activity, behavior, inaccurate data collection, hunting pressure, and population density. Ratios are probably most representative during the winter, when females are no longer under constraints of parental care. Sex determination should be made by experienced observers and preferably through internal examination. The most productive direction for interpretation of validated ratios appears to be in terms of population density, hunting pressure, and the timing of harvest.

INTRODUCTION
 Most published sex ratios for bobcats (Felis rufus) are based on rather static data accumulated over 1-3 years. These sex ratios (and explanations offered to explain them) have varied considerably, and some explanations are contradictory. Reported ratios have ranged from 0.40 males/female (Foote, 1945) to 2.21/1 (Kohn, 1981a). Sex ratios may change dramatically between years: the male-dominated ratio of Kohn (1981a) dropped to 1.10/1 the next year (Kohn, 1981b). Alternatively, Erickson (1955) demonstrated a gradual change in sex ratios of 6496 bountied bobcats from 0.97/1 in 1941 to 1.90/1 in 1952. Explanations offered for observed sex ratios in bobcats include: 1) greater mobility, thus vulnerability, of males; 2) lesser mobility, thus vulnerability, of females; 3) increased activity of either sex during the breeding season; 4) seasonal differences due to maternal care of young; 5) inaccurate sexing; 6) degree of hunting pressure; 7) density of the population; and 8) differential attractiveness to baits. The purposes of this paper are to consolidate thought on causes of observed sex ratios in bobcat populations and provide some insight into the applicability of these explanations.

METHODS AND MATERIALS
 When researchers feel that the sex ratio of a species is equal at birth, they look for causes when equality is not found in a sample. If the sample is of newborns, explanations usually invoke mechanisms for intrinsic population regulation such as sex-determining mechanisms and sex-specific intrauterine mortality. If the sample is from the general population, explanations often include differential mortality due to factors such as behavior or hunting pressure. The recent proliferation of data concerning sex ratios in bobcat populations has resulted in several explanations for ratios that deviated from equality. We examined literature reporting sex ratios in bobcat populations to evaluate the logic of explanations and to consolidate thought on the causes of unequal ratios, and to provide direction for future research. Most literature was located using publications of abstracting services and indexes for particular journals. In addition, letters were sent to several states to request information on bobcat research completed in those states.

RESULTS AND DISCUSSION
 Several researchers have suggested that male-dominated ratios are due to greater mobility of males, leading to increased vulnerability to trapping (Gashwiler et al., 1961; Pruitt and Sealander, 1978) or shooting (Knick et al., 1985). This argument is based on home range and movement studies that consistently indicate that males move farther and occupy larger ranges than do females (Robinson and Grand, 1958; Bailey, 1972; Hall, 1973; Guenther, 1980; Hamilton, 1982). If males are indeed more susceptible to trapping, then a female-dominated sex ratio in a sample reflects an even more female-dominated population in nature. McCord and Cardoza (1982), using the data of Donoho et al. (1979), argued that the sex ratio of specimens taken before and during the breeding season were similar, thus males were not more vulnerable due to reproductive activity. Interestingly, they stated that the seasonal differences found by Erickson (1955) showed no real variation, but examination of the original data indicated that males were collected in stronger disproportion during the summer (i.e., that females were more equally represented during the winter months).

Interpretations of proportions are often conceptually biased. Changing proportions may mean that one sex has become more susceptible, or that the other sex has become less so. Some literature deals with the question of why male vulnerability reflected in the ratio has changed, and doesn’t question whether changes in female vulnerability are responsible for observed changes. Sex ratios are often expressed as the number of males per female, suggesting that we may conceive of females as constants and males as variables. In contrast, Parker and Smith (1983) did suggest that males become less prone to trapping than females that were hunting and caring for kittens during the winter. This supposes that changes in female activity may result in changing sex ratios, that is, that male bias occurred because females were less likely to be trapped rather than males more likely to be.

Many trappers search for bobcat sign when locating trap sites. Because male range is larger than that of females, a trapper would more likely search for sign within a male bobcat’s range but would more likely find it in the more intensively utilized female’s range (McCord and Cardoza, 1982). Therefore, one might expect females to dominate in sex ratios due to an assumed greater chance of being located (Fredrickson and Rice, 1979; Klepinger et al., 1979). Most of the sex ratios in Table 1 suggest equality or male dominance, thus it is unlikely that females have a greater chance of being located by trappers.

Young (1958) described the success of a trapper who collected 321 bobcats in a 4-month period in Oregon. Females were not collected in substantial numbers until the latter part of October, when mothers and kittens began to travel. (Another interpretation may be that many of the males had been removed, leaving primarily females to trap.) Erickson (1955) and Gashwiler et al., (1961) found that female bobcats were proportionately more often collected during the winter months. This period represents the breeding season when parous females with previous litters are dispersing their young as mating begins. Females, therefore, become more mobile and effectively more trap-susceptible than in other seasons. Sex ratios observed during winter probably best reflect the existing ratios in most populations.
Table 1. Literature data on sex ratios of bobcats in North America.

<table>
<thead>
<tr>
<th>State or Region</th>
<th>Ratio (df/dV)</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vermont</td>
<td>0.60±</td>
<td>Foote, 1952</td>
</tr>
<tr>
<td>South Dakota</td>
<td>0.30±</td>
<td>Fritts and Rice, 1979</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>0.64±</td>
<td>Kleijngel et al., 1979</td>
</tr>
<tr>
<td>Virginia</td>
<td>0.87±</td>
<td>Frenzale, 1982</td>
</tr>
<tr>
<td>Oklahoma</td>
<td>0.87±</td>
<td>Bolley, 1983</td>
</tr>
<tr>
<td>California</td>
<td>0.84±</td>
<td>Lembeck, 1978</td>
</tr>
<tr>
<td>Kansas</td>
<td>0.95±</td>
<td>Johnson, 1979</td>
</tr>
<tr>
<td>Colorado</td>
<td>1.01±</td>
<td>Crowe, 1975</td>
</tr>
<tr>
<td>Montana</td>
<td>1.01±</td>
<td>McCord, 1978</td>
</tr>
<tr>
<td>Utah</td>
<td>1.07±</td>
<td>Sweeney, 1978</td>
</tr>
<tr>
<td>northeastern U.S.</td>
<td>1.05±</td>
<td>Sweeney, 1976</td>
</tr>
<tr>
<td>Washington</td>
<td>1.07±</td>
<td>Young, 1958</td>
</tr>
<tr>
<td>New Mexico</td>
<td>1.08±</td>
<td>Parker &amp; Smith, 1983</td>
</tr>
<tr>
<td>Nevada</td>
<td>1.08±</td>
<td>Koh, 1983</td>
</tr>
<tr>
<td>North Dakota</td>
<td>1.10±</td>
<td>Cashewell et al., 1961</td>
</tr>
<tr>
<td>Michigan</td>
<td>1.13±</td>
<td>Erickson, 1955 (bison)</td>
</tr>
<tr>
<td>Texas</td>
<td>1.20±</td>
<td>Blankenship &amp; Swanc, 1979</td>
</tr>
<tr>
<td>North Carolina</td>
<td>1.21±</td>
<td>King et al., 1983</td>
</tr>
<tr>
<td>Minnesota</td>
<td>1.22±</td>
<td>Ray, 1976</td>
</tr>
<tr>
<td>Arizona</td>
<td>1.26±</td>
<td>Young, 1958</td>
</tr>
<tr>
<td>Utah</td>
<td>1.26±</td>
<td>Cashewell et al., 1961</td>
</tr>
<tr>
<td>Idaho</td>
<td>1.27±</td>
<td>Bailey, 1979</td>
</tr>
<tr>
<td>Colorado</td>
<td>1.27±</td>
<td>Dombo et al., 1979</td>
</tr>
<tr>
<td>Texas</td>
<td>1.60±</td>
<td>Roberson, 1985</td>
</tr>
<tr>
<td>Michigan</td>
<td>1.54±</td>
<td>Erickson, 1955 (bounted)</td>
</tr>
<tr>
<td>Arkansas</td>
<td>1.59±</td>
<td>Fritts &amp; Sealandier, 1978</td>
</tr>
<tr>
<td>North Dakota</td>
<td>2.21±</td>
<td>Koh, 1981</td>
</tr>
</tbody>
</table>

* indicates a significant difference from an even ratio, Chi-square (p<0.05)

a the authors did not provide a reason for distinguishing a subgroup (N=792) of the total sample (N=28633).

Some researchers have compared sex ratios based on method of collection to gain insight on or to validate ratios. Erickson (1955) and Fritts and Sealandier (1978) found no significant difference between sex ratios in trapped versus hunted specimens. However, Kliejinger et al. (1979) suggested that hunters sometimes bias sex ratios by selecting only larger cats (males) due to trophy value. Brittell et al. (1979), Sweeney (1978), and Knick et al. (1985) noted that hound-hunted samples were male-biased while trapped samples had an even ratio. Therefore, comparisons of bobcat sex ratios calculated for hunted versus trapped specimens cannot be used for ratio validation. Still, distinction by method of collection does provide insight to the nature of bias in the samples.

Male-dominated sex ratios have been reported from Arizona, Arkansas, Colorado, Michigan, Minnesota, North Carolina, North Dakota, Texas, and Utah (Table 1). Because sexes are sometimes disproportionately collected during different seasons, the male dominance in some of these studies may be partially attributed to year-long collections (although Fritts and Sealandier (1978) felt that this had not affected the Arkansas sex ratio). Bailey (1972) found sex ratios to vary among age groups: 1.0/1 (kittens), 3.0/1 (transients), 0.6/1 (adults). Parker and Smith (1983) found males dominated the first age class, the ratio was even in young adults, and females dominated in older adults. Thus, different sizes of classes may result in sex ratios biased in favor of males (males dominate in younger, much larger classes). Additionally, male dominance in Texas (Roberson, 1981) may be partly explained by inaccurate sexing because ratios were based on furbuyer reports. Arkansas bobcat sex ratios determined from buyer reports favor males (1.5:1; L. Johnston, pers. commun.) but the ratio determined from carcasses collected during the same period approximated a 1:1 distribution (Tumilson, 1983), possibly because bobcats are more difficult to sex than most furbearers. McCord and Cardoza (1982) reported bobcat sex ratios determined by wildlife biologists in Vermont heavily favored females until verification by internal examination revealed an almost equal sex ratio.

A postscript in Fredrickson and Rice (1979) indicated that the female-biased ratio in South Dakota approached a 1:1 distribution based upon internal examination of carcasses collected during the succeeding year. Females were strongly dominant in Vermont, Wisconsin, and South Dakota samples (Table 1). More harsh northern climates might require a female-dominated population for higher reproduction to offset higher mortality due to greater winter stress. Sex ratios from North Dakota and Washington do not support this interpretation. Further, McCord and Cardoza (1982) alluded to Foot’s (1945) female-dominated ratio when they provided information discounting the credibility of early sex ratios from Vermont.

Logically, a female-dominated population would optimally effect a population increase in a polygynous species. Mech (1975) found that sex ratios of wolf (Canis lupus) pups varied according to population density, with more males indicating significant in litters from high density populations. Conversely, an equal sex ratio or a preponderance of females was produced when the population had been exploited and had existed at a lower density. In a resource-limited environment, a preponderance of males would tend to stabilize the growth rate of the population by decreasing the percentage of breedable females and thereby prevent over-utilization of limited resources. Assuming bobcat reproduction is a density-dependent function, then, male-dominated sex ratios may indicate saturated or unexploited populations. Lembeck and Gould (1979) found a preponderance of males in high-density bobcat populations and females in low-density populations.

Recent estimates of the sex ratio for Arkansas bobcats (Tumilson, 1983) indicated a 1:1 distribution, although Fritts and Sealandier (1978) determined too few ratios of 1:69/1:1 in Arkansas a decade earlier. Their data represented an unexploited and probably high-density population, whereas the present population is exploited. If the findings of Mech (1975) for low-density versus high-density wolf populations are applicable to bobcats, exploitation may partially account for the disparity between present and previous bobcat sex ratios in Arkansas. Alternatively, hunting pressure itself may be responsible for the change in sex ratios from Arkansas. Gilbert (1979) suggested hunting pressure might be responsible for skewed ratios in bobcats based on similar research with black bears (Ursus americanus). As hunting pressure increases, the effect of different home range size decreases and sex ratios in the kill approach equality. Sex ratio, then, may reflect harvest pressure. Gilbert (1979) cited Lembeck and Gould (1979) as support, however Erickson (1955) found male-bias to increase with increasing harvests.

Gilbert (1979) tried to explain even sex ratios as being the result of an excess of available females in older age classes. He cited Crow and Strickland (1975) and Fritts and Sealandier (1978) to support the concept of greater vulnerability of males, stating that young males had a greater chance of being caught, leaving more females available in older age classes. However, the number of "surplus" females in older age classes found by Fritts and Sealandier (1978) is insufficient to balance the loss of males in younger age classes, thus the sex ratio was not equal (1.69/1). The sex ratio reported by Crowe and Strickland (1975) was equal, and males did dominate younger and females older age classes. However, almost one third of their total sample was killed, thus Gilbert (1979) assumed the sex ratio in that part of the total sample ws proportionate to that of the sexed samples. If this assumption is false, the inferences made could also be false.

The timing of the harvest season is another important factor in the interpretation of sex ratios. With extended seasons, an increase in the proportion of kittens of both sexes occurs in exploited populations (Parker and Smith, 1983; Knick et al., 1985). Because sex ratios in younger age classes often favor males (Bailey, 1972; Parker and Smith, 1983; Knick et al., 1985), later or extended seasons will likely produce more males and earlier seasons relatively fewer females.

Other explanations for bias in observed sex ratios of bobcats are of interest. Too few data are available to do more than note them here. Young (1958) thought differential attractiveness to baits may cause biases in trapping data. Fritts and Sealandier (1978) suggested that higher postnatal mortality of female kittens might occur in the event of intraspecific competition for food, and that smaller females might have lower survivorship after maternal care was withdrawn.

CONCLUSION

It is evident that explanations given for observed sex ratios in bobcat populations are not always consistent or biologically defensible. Greater mobility of males as an explanation of male-dominated ratios versus lesser mobility of females as an explanation of female-dominated populations need further research. Further, the data used in the development of sex ratio determinations is viewed more critically, and the potential for the influence of environment on sex ratio determination is recognized.
Sex Ratios in Bobcat Populations

ratios is obviously inconsistent. Females (but not males) probably become more susceptible to trapping during the breeding season. Ratios must be based on sex determined by internal examination. Perhaps future analyses of sex ratios should focus upon population density, hunting pressure, and timing of the harvest season because these hypothesized causes are biologically sound. At present, data are insufficient to determine their value as explanations.

LITERATURE CITED


FOREST HABITAT USE BY WHITE-TAILED DEER IN THE ARKANSAS COASTAL PLAIN

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ABSTRACT

Forest habitat use by five radio-equipped white-tailed deer (Odocoileus virginianus) was monitored in the Arkansas Coastal Plain during 1982-84. The deer were located 821 times. Use of forest types was compared to expected use as calculated from availability. The study area was also divided into 491 two-hectare cells for which timber characteristics and number of deer locations were determined. Pine sawtimber was the most heavily used forest type in all seasons and was used more often than expected during spring. Also used more than expected were brushy areas (clearcut but not site prepared) during spring, summer and fall and openings (grass fields and a site-prepared clearcut) during summer. Hardwood stands were used less often than expected during every season. Also used less than expected were pine pulpwood stands in summer and pine-hardwood stands during spring and summer. A significant (P < 0.001) discriminant function correctly classified 74% of the two-hectare cells as used (1 + locations) or not used (0 locations). Used cells often had less hardwood pulpwood and sawtimber and more pine sawtimber than nonused cells. Use by deer of cells containing stand edges did not differ from use of cells without edges.

INTRODUCTION

The white-tailed deer (Odocoileus virginianus) is an important natural resource in Arkansas. In Arkansas, an estimated 66,000 deer were harvested during the 1983-84 season by 217,600 hunters (Cartwright, 1984). Forty-eight percent of the 1983-84 Arkansas deer harvest was from the Coastal Plain region (Cartwright, 1984).

Forests provide most of the habitat for white-tailed deer and much of the area used for deer hunting. About one-half of Arkansas is forested. The Coastal Plain, the region of the state most heavily used for deer hunting, is 73% forested (USDA Forest Service, 1979). In 1984, Arkansas produced about 4% of the total United States wood products (Kluender et al., 1988). To meet the needs of the Arkansas forest industry, large areas of Coastal Plain forest are intensively managed. Therefore, large areas of deer habitat in Arkansas are influenced by forest management. The objective of this study was to determine forest habitat use by white-tailed deer in the Arkansas Coastal Plain.

METHODS

This study was conducted on the 285-ha University of Arkansas at Monticello Forest and about 190 ha of surrounding forest owned by Georgia-Pacific Corporation. The area is located about 5 km east of Monticello in Drew County, Arkansas, and is typical of the Coastal Plain physiographic region of the southeastern United States. Even-aged stands of loblolly (Pinus taeda) and shortleaf (P. echinata) pine (20 to 45 years old), and unevenaged pine, hardwood and mixed pine-hardwood stands dominate the area (Table 1). Also present are brushy areas (clearcut but not site prepared) and openings such as a site-prepared, unplanted clearcut and grassy fields (Table 1). Dominant hardwood species are sweetgum (Liquidambar styraciflua), hickories (Carya spp.), southern red oak (Quercus falcata), water oak (Q. nigra) and willow oak (Q. phellos). Ground-level woody vegetation is characterized by American beauty-berry (Callicarpa americana), blueberry (Vaccinium spp.), greenbrier (Smilax spp.), Japanese honeysuckle (Lonicera japonica) and blackberry (Rubus spp.).

Timber inventory data routinely collected on the study area were used. Data available for hardwood and pine, and pulpwood and sawtimber included basal area (BA), diameter at breast height (dbh), volume and the number of stems per acre. Pine trees from 15.2 to 25.1 cm dbh and hardwood trees from 15.2 to 30.2 cm dbh were classed as pulpwood. Trees with larger dbh were termed sawtimber. Stands were classed as pulpwood or sawtimber stands if the average dbh of all trees was within these specified ranges. Stands were categorized as pine if > 75% of the BA was in pine, as hardwood if > 75% of the BA was in hardwood, and as hardwood if pine and hardwood each accounted for 25-75% of the BA. The term total, as used in this study, refers to timber characteristics of all trees.

Five white-tailed deer (three 1.5-year-old males and two 1.5-year-old females) were captured on the study area during 1982 to 1983 using box traps. Each deer was fitted with a collar-mounted radio transmitter operating in the 151 MHz range and released at the capture-site. The deer were located at randomly-selected times from 20 October 1982 to 15 October 1984. Locations were determined using two bearings that differed by 45-90 degrees and were taken less than 10 minutes apart and less than 0.40 km from the deer.

Table 1. White-tailed deer use of Arkansas Coastal Plain forest stands by forest type and season, 1982-84.

<table>
<thead>
<tr>
<th>Forest Type</th>
<th>% of Locations</th>
<th>Spring</th>
<th>Summer</th>
<th>Fall</th>
<th>Winter</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pine</td>
<td></td>
<td>53</td>
<td>29</td>
<td>14</td>
<td>11</td>
<td>10</td>
</tr>
<tr>
<td>Sawtimber</td>
<td></td>
<td>28</td>
<td>12</td>
<td>14</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Pine</td>
<td></td>
<td>10</td>
<td>5</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Pulpwood</td>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Hardwood</td>
<td></td>
<td>22</td>
<td>9</td>
<td>11</td>
<td>21</td>
<td>19</td>
</tr>
<tr>
<td>Pine</td>
<td></td>
<td>22</td>
<td>9</td>
<td>11</td>
<td>21</td>
<td>19</td>
</tr>
<tr>
<td>Pulpwood</td>
<td></td>
<td>4</td>
<td>11</td>
<td>19</td>
<td>9</td>
<td>15</td>
</tr>
<tr>
<td>Hardwood</td>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Pine</td>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Pulpwood</td>
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<td>11</td>
<td>19</td>
<td>9</td>
<td>15</td>
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<tr>
<td>Hardwood</td>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Pine</td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Pulpwood</td>
<td></td>
<td>4</td>
<td>11</td>
<td>19</td>
<td>9</td>
<td>15</td>
</tr>
</tbody>
</table>

Symbols indicate use significantly (P < 0.05) more (+) or less (-) than expected, based on availability.


BA was in hardwood and as pine-hardwood if pine and hardwood each accounted for 25-75% of the BA. The term total, as used in this study, refers to timber characteristics of all trees.

Five white-tailed deer (three 1.5-year-old males and two 1.5-year-old females) were captured on the study area during 1982 to 1983 using box traps. Each deer was fitted with a collar-mounted radio transmitter operating in the 151 MHz range and released at the capture-site. The deer were located at randomly-selected times from 20 October 1982 to 15 October 1984. Locations were determined using two bearings that differed by 45-90 degrees and were taken less than 10 minutes apart and less than 0.40 km from the deer.

The number of locations in each habitat type on the study area was determined, and habitat use and availability were compared using the Bonferroni z-statistic (Neu et al., 1974). All forest stands on the study area were assumed to be available to the deer. The expected number of locations in each forest type was calculated as the product of the total number of deer locations and the proportion of the study area in that forest type (Neu et al., 1974). The terms preference, preferred, or greater than expected, as used in this study, indicate statistically preferred forest type and season, 1982-84.
greater use of a forest type than the calculated expected value. The terms avoided or less than expected indicate use statistically less than the expected value.

A map of the study area was divided into 2-ha square cells, and timber inventory data were determined for each cell. For cells containing the edges of 2 or more stands, the timber inventory data for the predominant stand were used. The degree of contrast in each timber characteristic along stand edges occurring in the cells were also measured. For cells with no stand edges, values of 0 were assigned to the difference variables.

The number of deer locations was counted for each 2-ha cell and cells were classified as used (1 + deer location) or not used (0 location) for each season and for the entire study period. Timber characteristics of used and nonused cells were analyzed using discriminant analysis (Norusis, 1988). Two stepwise discriminant analyses were used to minimize multicollinearity (Sanathanan, 1975). Minimization of Wilks' lambda was the variable selection criteria. The average values of timber characteristics selected for the discriminant functions were compared between used and nonused cells using an F-test. Contingency table analysis was used to test for preferential use of 2-ha cells containing stand edges. Significance was accepted at the 0.05 probability level.

RESULTS AND DISCUSSION

The deer were located 821 times over the study period. Pine sawtimber was the most heavily used forest type (Table 1) and was used more than expected during spring and the entire study period. Brushy areas were preferred habitat during spring, summer, and fall, and for the entire study period. Openings were used more than expected during summer.

Three forest types were used less than expected based on their availability. Although 12% of all locations were in hardwood stands, this habitat type was used less than expected during every season and over the entire study period (Table 1). Pine-hardwood stands were avoided during spring and summer, and pine pulpwood stands were used less than expected during summer (Table 1).

Seventeen stand characteristics were chosen for the function discriminating between used and nonused 2-ha cells (Table 2). The function correctly classified 74% of all cells and 82% of used cells. Two- and three-story stands used by deer had more basal area and volume in pine pulpwood than cells that were not used. Used cells also had more pine sawtimber basal area, a greater pine sawtimber dbh, more sawtimber (pine and hardwood) stems and basal area and a greater total dbh than nonused cells. Used cells were located in stands with less perimeter (km of edge) length and more area than stands in which nonused cells were located.

Cells containing stand edges were not used at a rate different from cells without edges during any season or over the entire study period. Thirty-nine percent of all 2-ha cells contained edges of 2 or more stands. Of used cells, 42% contained stand edges. Cells containing high-contrast edges (a difference of > 25 sawtimber stems/ha), however, were used more often (56% vs. 41%) than cells with less contrast in number of sawtimber stems (x<sup>2</sup> = 8.86, 1 df, P = 0.003). Used cells had less contrast across edges in hardwood pulpwood basal area and volume (Table 2).

We feel that the preferential use of pine sawtimber stands, brushy areas and openings were related to the abundance of ground-level vegetation in these habitats. Although the diet of white-tailed deer in Coastal Plain forests is highly variable and changes seasonally (Newcomb, 1984), forbs and the leaves and succulent twig tips of woody plants are preferred foods (Blair and Brunett, 1980). Thill (1984) found in Louisiana that about 90% of deer diet was woody browse, ranging from 85% in winter to 92% in fall. Forb usage varied from 6% in fall to 14% in winter. Hard and soft masts comprised less than 1% of deer diet in all seasons except in fall when they accounted for about 20% of diet.

The production of these foods in southern forests has been related in other studies to overstory characteristics (Halls, 1970; Blair and Brunett, 1977; Wiggers et al., 1978; Hurst et al., 1979; Fenwood et al., 1984). Browse, forb and grass production is inversely related to basal area and number of forest layers (Halls and Schuster, 1965; Blair, 1967; Blair and Enghardt, 1976; Wiggers et al., 1978; Hurst et al., 1979). Soft and hard mast yields may also decrease as stand density increases (Blair, 1969).

In most southern forests, a dense multilayered midstory of hardwoods inhibits forage growth (Schuster and Halls, 1963; Blair, 1969; Blair and Enghardt, 1976; Blair and Feduccia, 1977). A dense hardwood midstory may also cause undesirable changes in forage production by decreasing total number of species, the number of palatable species and plant vigor (Schuster and Halls, 1963; Blair, 1967). In older stands with little hardwood midstory, more light reaches the forest floor than in stands with a midstory or in younger stands with low, dense canopies (Blair, 1969).

Used 2-ha cells and preferred forested habitats in this study usually had an open pine sawtimber overstory, little hardwood midstory and abundant browse available. Eighty-one percent of the locations in forested habitats were in stands with less than 25% of standing volume in hardwood pulpwood. Fifty-seven percent of locations in forested habitats were in stands in which hardwood comprised less than 25% of the sawtimber basal area. Brushy and open areas also had abundant deciduous browse such as Japanese honeysuckle, American beautyberry, blackberries, oaks and red maple (Acer rubrum) that remained available into late fall.

Conversely, habitats used less than expected often had a dense hardwood midstory that shaded forage. For example, 2-ha cells that were not used during spring had more stems, basal area and volume in hardwood sawtimber than cells that were used. Cells not used during spring and summer had more stems and basal area in hardwood pulpwood than used cells. The pine pulpwood stands used less than expected were without a hardwood midstory but typically had low, closed canopies and less forage than sawtimber stands.

CONCLUSIONS

Habitat use by white-tailed deer in the Arkansas Coastal Plain is complex and explainable only by simultaneous consideration of many habitat characteristics. The results of this study, however, suggest that forest characteristics influence habitat use. Openings and pine sawtimber stands with little hardwood midstory were preferred, probably because these characteristics are usually associated with increased forage production.

Cultural practices that reduce overstory density and minimize hardwood midstory formation will ensure adequate light to the understory.
Forest Habitat Use by White-Tailed Deer in the Arkansas Coastal Plain

and enhance habitat quality (Blair, 1969). Hardwood control should be used when making routine thinnings in managed stands to avoid development of a dense midstory (Blair and Feduccia, 1977). Preferential edge use by white-tailed deer has been reported (Williamson and Hirth, 1985). However, only edges offering high contrast in the number of sawtimber stems were preferentially used by deer in this study.

ACKNOWLEDGEMENTS

The authors thank the Arkansas Agricultural Experiment Station for financial support of this research and the Arkansas Game and Fish Commission for their assistance. A special debt is owed B. Cantrell, L. Caton, R. Crossett, L. Davis, K. Flenniken and D. Sharer.

LITERATURE CITED


SEEDLING GROWTH RESPONSE IN A GREENHOUSE TO FOUR RATES OF OLD AND NEW PAPER MILL SLUDGE

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University of Arkansas at Monticello
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ABSTRACT

Four rates (0, 36, 75, and 112 DT/A) of both old and new pulp-mill sludges were tested in a greenhouse for impact on survival and growth of seedlings of loblolly pine (Pinus taeda L.). After one growing season no meaningful differences were detected for seedling survival and growth, number of flushes, and decomposition rate for old and new sludges regardless of rate. Seedling foliage showed increases in Mg and Ca and sludges exhibited high pH and increased salinity.

INTRODUCTION

Dewatered sludge from pulp and paper mills is known to stimulate agronomic crop production and could potentially stimulate pine seedling growth. Concerns associated with sludge application to selected pine sites include (1) a high sludge pH and calcium carbonate equivalency, which could rate soil pH above a desirable level for loblolly pine and alter the species composition of the herbaceous community on the site, (2) the presence of salts that could kill pine seedlings, (3) the duration during which salts persist in the soil, (4) a high carbon to nitrogen ratio known to immobilize nitrogen and thereby detrimentally influence pine growth, (5) increased levels of nutrient availability, which in the absence of weed control could enhance the growth of herbs to the detriment of pine seedling survival and growth, (6) numerous water soluble nutrients that may enter the ground water, (7) low levels of heavy metals in the sludge that accumulate in the soil and could limit reapplication of sludge, and (8) the intricate relationships between seasonal patterns of rainfall and temperature, availability of nitrogen, quantity and quality of sludge and soil texture as they relate to sludge decomposition rate, nutrient release, soil penetration, ground water percolation and tree uptake.

Deposition of mill sludge is generally achieved through a chain of sediment ponds or placement in a pit. One pulp and paper company spends over $125,000 annually on sludge deposition and pit maintenance. With seven pulp and paper mills in Arkansas, the annual cost to Arkansas' pulp and paper industry probably exceeds one million dollars annually. This large number is disturbing considering sludge deposition is totally a liability on the industry. A use for the mill sludge is needed.

The objectives of this study are: (1) to compare growth in height and groundline diameter, number of flushes, and nutrient constituents of needles from greenhouse-grown seedlings receiving postplant applications of 0, 36, 75 and 112 dry tons per acre (DT/A) of old or new sludge, (2) to contrast the nutrient constituents and electrical conductivity of sludge at the beginning and the end of the study, and (3) to examine rates of decomposition for sludge treatments.

MATERIALS AND METHODS

Seedling Care

One hundred and seventy bare-root seedlings were planted during the third week of February in 7-gallon pots and placed in a greenhouse. Pots contained five gallons of a 1:1 mixture of peat moss and vermiculite plus a 6-month, timed-release fertilizer containing nitrogen, phosphorus and potassium. Media were watered to saturation twice weekly. Care was taken to avoid flushing pots with excessive water.

Seedlings began breaking bud in mid-March, at which time they received the first of three weekly applications of selected nutrients (Table 1). Potting media were glazed with fertilizer and followed with sufficient water to move the nutrients throughout the root zone. It should be noted that only nitrogen, phosphorus, and potassium continued to be provided by the timed-release fertilizer. Some additional nutrients were released by the decomposing sludge.

Table 1. Fertilization regime for the first three weeks of the greenhouse study.

<table>
<thead>
<tr>
<th>Element</th>
<th>Concentration (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>150.0</td>
</tr>
<tr>
<td>P</td>
<td>150.0</td>
</tr>
<tr>
<td>K</td>
<td>150.0</td>
</tr>
<tr>
<td>Ca</td>
<td>50.0</td>
</tr>
<tr>
<td>Mg</td>
<td>20.0</td>
</tr>
<tr>
<td>Cu</td>
<td>0.010</td>
</tr>
<tr>
<td>B</td>
<td>0.100</td>
</tr>
<tr>
<td>Mn</td>
<td>0.250</td>
</tr>
<tr>
<td>Zn</td>
<td>0.100</td>
</tr>
<tr>
<td>Mo</td>
<td>0.010</td>
</tr>
<tr>
<td>Fe</td>
<td>10.9</td>
</tr>
<tr>
<td>S</td>
<td>84.0</td>
</tr>
<tr>
<td>Cl</td>
<td>133.9</td>
</tr>
<tr>
<td>Na</td>
<td>111.1</td>
</tr>
</tbody>
</table>

1 A 6-month, timed-release source of nitrogen, phosphorus, and potassium was used. All other elements were in three, weekly applications.

Sludge Treatments

Seedlings were grown for approximately one month and then screened prior to the application of sludges. Those seedlings with an injury, brown needle-tips, or other signs of stress or abnormality were discarded. All seedlings were retained in the study once sludges were applied.

Both sludges used in this study originated from a Kraft pulp and paper mill near Ashdown, AR. The old sludge had been in a disposal pit for approximately one year. The new sludge was fresh from the mill. Samples of sludges were weighed, oven-dried, and reweighed to determine the percent content. Sufficient timed-release fertilizer was mixed with the sludges to bring the C:N to 20:1. During the second week in April, old and new sludges were applied to 84 seedlings at wet rates equivalent to 0, 36, 75, and 112 DT/A.
Seedling Growth Response in a Greenhouse to Four Rates of Old and New Paper Mill Sludge

Morphological Analysis
Seedlings were measured at the time of planting for height (HT) and
groundline diameter (GLD). Incremental height and groundline diameter
were determined as follows:
Total HT − Initial HT = Incremental HT
Total GLD − Initial GLD = Incremental GLD

Nutrient Analysis
Initial nutrient levels were computed by averaging data from 12
sacrificed seedlings. In July four to six grams (green weight) of needles
were collected from each seedling. Samples were collected from the south
side of the upper one third of the crown according to the methods of
White (1954) and Wells and Metz (1963).
As collected, samples were sealed in plastic bags and immediately
placed in a refrigerator. In the laboratory, the needles were rinsed in
distilled water, 1% HCL, and three distilled demineralized water baths.
Needle samples were then dried at 65°C in a forced-air oven. After
drying, the tissue was ground in a Wiley mill using a 20-mesh stainless steel
slice and stored in air tight bottles.
At the initiation of the project and again in July, a sample of old
and new sludges were collected from each pot for analysis. Sludges were
not washed prior to analysis.
The concentration of phosphorus was determined by the colorimetric
method (Trough and Meyer, 1929). Standard atomic absorption tech-
niques (Issac and Kerber, 1971) were used to determine concentrations
of calcium (Ca), magnesium (Mg), sodium (Na), and potassium (K).
A conductivity meter was used to measure the electrical conductivity
of aqueous sludge samples.

Statistical Analysis
The study was conducted as a randomized block design with three
blocks. Analyses of variance and covariance were used to evaluate treat-
ment differences. Duncan’s Multiple Range test was used to contrast
means. Dependent variables were growth in height (cm) and groundline
diameter (mm), survival (%), number of flushes per tree, and DT/A
of decomposed sludge. Initial height and initial groundline diameter
were the covariates. All statistical tests were conducted at the 0.05
probability level.

Table 2. Seedling growth and decomposition of old and new sludge
Initial groundline diameter (GLD), initial height (HT) and rate of
application were covariates.

<table>
<thead>
<tr>
<th>Sludge Age</th>
<th>Survival</th>
<th>Initial GLD</th>
<th>Incremental GLD</th>
<th>No of Flushes</th>
<th>Sludge Decomposition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HT cm</td>
<td>GLD cm</td>
<td>HT cm</td>
<td>GLD cm</td>
<td>cm cm</td>
</tr>
<tr>
<td>Check</td>
<td>92 B 4</td>
<td>23 4</td>
<td>32 A 6</td>
<td>3 A 0</td>
<td>0 B</td>
</tr>
<tr>
<td>New</td>
<td>97 A 23</td>
<td>4 36 A 6</td>
<td>3 A 29 A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Old</td>
<td>89 B 24</td>
<td>5</td>
<td>39 A 6</td>
<td>3 A 32 A</td>
<td></td>
</tr>
</tbody>
</table>

1 Means within a column sharing the same letter are not significantly
different at the 0.05 level (Duncan’s Multiple Range test).
2 Based on mid-April and mid-August dry weights of sludge.

RESULTS AND DISCUSSION

Sludge Age
Seedlings growing in new sludge exhibited higher survival than seed-
lings growing in old or no sludge (Table 2). Only six seedlings died: one
in no sludge, one in new sludge and four in old sludge. Survival percent-
ages are high enough that at normal planting rates mortality would not
be of operational significance.
No significant differences were detected in height growth, groundline
diameter growth or number of growth flushes per tree (Table 2). Seed-
lings receiving sludge treatments responded with at least similar growth
in height or groundline diameter as untreated check seedlings regardless
of the age of the sludge. No inhibition of growth was detected.
The proportion of applied sludge remaining in August was similar
for old and new sludges. This suggests that allowing fresh sludge to
age for a year in the sludge pit had no effect on the subsequent rate of
decomposition after it was spread in the field. It appears then that
greater or additional applications are no more possible for old than
new sludges.

Rate of Application
Analyses showed no differences in seedling survival, growth, number
of growth flushes or sludge decomposition rate occurred as a result of
application rate (Table 3). It is important to realize that sludge treated
seedlings did not grow significantly more or less than untreated check
seedlings. Therefore, stimulation or inhibition of seedling growth was
not detected.

Sludge Age By Rate of Application Interaction
A statistically significant interaction between age of sludge and rate
of application was detected for seedling survival (Table 4). Results show
that survival was best for seedlings growing in new sludge or 36 DT/A
of old sludge. However, the sample size was such that each dead seed-
ling represents an 8% decrease in survival. Therefore, the two high rates
of old sludge each had two dead trees while the check and the low rate
of new sludge each had one dead tree. These differences are probably
not meaningful. A significant interaction was not detected for the growth
parameters or number of flushes per tree.

Nutrient Analysis
There were no major differences in sludge nutrient levels for P, Na,
Mg, or Ca related to age or rate of application. Sludge salt levels, as
measured by electrical conductivity, were observed to increase between
March and July while sludge alkalinity and K decreased (Table 5).
Changes in these values probably resulted from partial decomposition
of sludges and/or the presence of fertilizer.
There were some differences in follic nutrient levels. Needles of live
seedlings treated with sludge contained higher levels of Mg and Ca but

Table 3. Seedling responses to 0, 36, 75 and 112 dry tons per acre (DT/A)
of sludge. Initial groundline diameter (GLD), initial height (HT) and
rate of application were covariates.

<table>
<thead>
<tr>
<th>Sludge Rate</th>
<th>Survival</th>
<th>Initial GLD</th>
<th>Incremental GLD</th>
<th>No of Flushes</th>
<th>Sludge Decomposition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HT cm</td>
<td>GLD cm</td>
<td>HT cm</td>
<td>GLD cm</td>
<td>cm cm</td>
</tr>
<tr>
<td>Check 0</td>
<td>92 B 4</td>
<td>23 4</td>
<td>32 A 6</td>
<td>3 A 0</td>
<td>0 B</td>
</tr>
<tr>
<td>New 36</td>
<td>97 A 23</td>
<td>4 36 A 6</td>
<td>3 A 29 A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Old 75</td>
<td>89 B 24</td>
<td>5</td>
<td>39 A 6</td>
<td>3 A 32 A</td>
<td></td>
</tr>
</tbody>
</table>

1 Means within a column sharing the same letter are not significantly
different at the 0.05 level (Duncan’s Multiple Range test).
2 Based on mid-April and mid-August dry weights of sludge.

Table 4. Seedling responses to four rates of old and new sludge. Initial
groundline diameter (GLD), initial height (HT) and rate of application
were covariates.

<table>
<thead>
<tr>
<th>Sludge Rate</th>
<th>Survival</th>
<th>Initial GLD</th>
<th>Incremental GLD</th>
<th>No of Flushes</th>
<th>Sludge Decomposition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HT cm</td>
<td>GLD cm</td>
<td>HT cm</td>
<td>GLD cm</td>
<td>cm cm</td>
</tr>
<tr>
<td>Check 0</td>
<td>92 B 4</td>
<td>23 4</td>
<td>32 A 6</td>
<td>3 A 0</td>
<td>0 B</td>
</tr>
<tr>
<td>New 36</td>
<td>97 A 23</td>
<td>4 36 A 6</td>
<td>3 A 29 A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Old 75</td>
<td>89 B 24</td>
<td>5</td>
<td>39 A 6</td>
<td>3 A 32 A</td>
<td></td>
</tr>
</tbody>
</table>

1 Means within a column sharing the same letter are not significantly
different at the 0.05 level (Duncan’s Multiple Range test).
2 Based on mid-April and mid-August dry weights of sludge.

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102
CONCLUSIONS

In conclusion, results showed both sludges have potential for field application and should be field tested. Neither sludge stimulated nor inhibited seedling survival or growth. Nutrients in seedling foliage were generally within accepted normal levels. Increases in Mg, Ca, pH and electrical conductivity suggest future studies should examine the potential impact of salts and lime on both seedling development and site quality. Mill sludge should be tested as a mulching agent to increase soil moisture by reducing competition from herbaceous plants. Incorporating sludge into the soil prior to planting should also be evaluated for its impact on seedlings and site quality.

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SURVIVAL AND GROWTH TWO YEARS AFTER CONTROL OF HERBACEOUS COMPETITORS IN NEWLY PLANTED SEEDLINGS OF LOBLOLLY PINE

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ABSTRACT
Early or late over-the-top applications of herbicides were used to control herbaceous competition in machine planted loblolly pine (Pinus taeda L.) seedlings at two locations in a pasture near Alleene and hand planted seedlings on a beaded site near Fouke. Sites were selected for diverse competitors. None of the treatments controlled weeds for the entire growing season. Only glyphosate + sulfometuron methyl produced seedling survival and growth below the check plots. The best over-the-top treatments were sulfometuron methyl alone or sulfometuron methyl + hexazinone.

INTRODUCTION
Forest managers are beginning to realize the importance of controlling herbaceous competitors about newly planted pine seedlings. A recognition of the potential contribution of early weed control to total site productivity has stimulated investigations on the impact of specific herbicides on early pine seedling development.

Studies using potted seedlings and various watering regimes have demonstrated a strong positive correlation between soil moisture and growth of loblolly pine (Wenger, 1952; Zahn, 1962). Likewise, field studies by Stransky (1961) and Koshi and Stephenson (1962), showed a positive relationship between growth and soil moisture when weeds were controlled. In addition, growth of loblolly pine seedlings was inversely related to herbaceous weed cover or biomass following weed control treatments (Nelson et al., 1981). Depending on the site, percentage of herbaceous cover seven weeks after herbicide treatment explained 43 to 81% of the variation in first-year height growth of loblolly pine. In another study of low, medium, or high levels of herbaceous control, first-year pine growth was most likely correlated to soil moisture level in late August, when soil moisture was lowest (Zutter et al., 1986). From a summary of studies in herbaceous competition in 16 plantations largely in Alabama, researchers showed first, competition control had a significant positive effect on height and diameter at all 16 locations, and on survival or density when competition was intense. Second, a second year of herbaceous vegetation control led to significant additional gains in height and diameter at six and seven of 10 locations, respectively. And third, application technique did not significantly influence survival, or growth in height and groundline diameter (Creighton et al., 1987). Increased growth in these studies was presumably due to increased soil moisture, nutrient availability and light availability as a result of removing competing herbs.

Much of the research in the South on herbaceous competitors has focused on traditional Coastal Plain sites and its competitors. Problem competitors often associated with poor soil drainage and non-timbered sites need to be examined and justifies the establishment of this study.

OBJECTIVES
The objectives of this study were to compare (1) the efficacy of selected herbicides on herbaceous competitors found on newly planted pine sites and (2) the growth response of newly planted pine seedlings to release from these competitors.

METHODS
Three sites were included in this study. Locations one and two were in a pasture near Alleene, AR. Location one supported mixed grasses (Digitaria spp., Panicum spp., Crotan sp., Carex spp., and Festuca sp.) while location two had a dense bermudagrass (Cynodon dactylon) sod. These sites were machine planted in February 1986. Location three was near Fouke, AR. It was prepared by shearing, windrowing and bedding prior to hand planting in February 1986. The bedding was completed in November 1985.

Seedling buds and bermudagrass were evaluated for dormancy prior to the application of early (March 20) and late (April 22) treatments. On March 20, Fouke seedlings received early treatments of herbicides and were evaluated as 10% flushed, 20% swollen, and 70% dormant. At Alleene, locations one and two were given the same assessment: 10% flushed, 50% swollen, and 40% dormant. On July 2, Fouke seedlings were released with late treatments of herbicides and assessed as 100% flushed. At Alleene, late treatments were applied on April 22 and seedling buds assessed as 90% flushed, 5% swollen and 5% dormant. Bermudagrass was absent at Fouke and 10% green at Alleene.

Herbicides (Tables 1 and 2) were applied over-the-top in 1-meter bands centered over seedlings. No effort was made to protect seedlings from contact with herbicides. Herbaceous biomass was collected from a 1-meter square in each check plot at all sites. Samples were taken 30, 60, 90 and 120 days after treatment (DAT).

Percent reduction of herbaceous competition as compared to check plots was evaluated in 10% intervals for each plot. Evaluations were performed 30, 60, 90 and 120 DAT.

Table 1. Herbicides tested.

<table>
<thead>
<tr>
<th>Trade Name</th>
<th>Common Name</th>
<th>Registered Trademark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Escort</td>
<td>mesulfuron methyl</td>
<td>E. I. du Pont de Nemours &amp; Company</td>
</tr>
<tr>
<td>Fusilade</td>
<td>fluazifop</td>
<td>ICI America Inc.</td>
</tr>
<tr>
<td>Osat</td>
<td>sulfometuron methyl</td>
<td>E. I. du Pont de Nemours &amp; Company</td>
</tr>
<tr>
<td>Post</td>
<td>sethoxydim</td>
<td>BASF Wyandotte Corporation</td>
</tr>
<tr>
<td>Roundup</td>
<td>glyphosate</td>
<td>Monsanto Chemical Company</td>
</tr>
<tr>
<td>Velpar L</td>
<td>hexazinone</td>
<td>E. I. du Pont de Nemours &amp; Company</td>
</tr>
</tbody>
</table>
Table 2. Mean percent control of herbaceous competitors.

<table>
<thead>
<tr>
<th>Treatment (kg/ha a.i.)</th>
<th>Days After Treatment</th>
<th>Alleene (Mixed Grasses)</th>
<th>Alleene (Bermudagrass)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>30</td>
<td>60</td>
<td>90</td>
</tr>
<tr>
<td><strong>Efficacy</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E 0.15 Sulf^2</td>
<td>93</td>
<td>92A</td>
<td>79</td>
</tr>
<tr>
<td>E 0.28 Sulf</td>
<td>93</td>
<td>92A</td>
<td>86AB</td>
</tr>
<tr>
<td>E 0.56 Hex+0.15 Sulf</td>
<td>99A</td>
<td>97A</td>
<td>87AB</td>
</tr>
<tr>
<td>E 0.36 Gly+0.15 Sulf</td>
<td>99A</td>
<td>95A</td>
<td>85AB</td>
</tr>
<tr>
<td>E 0.36 Gly+0.28 Sulf</td>
<td>99A</td>
<td>95A</td>
<td>85AB</td>
</tr>
<tr>
<td>L 0.43 Flo+0.15 Sulf</td>
<td>93</td>
<td>96B</td>
<td>58</td>
</tr>
<tr>
<td>L 0.43 Flo+0.28 Sulf</td>
<td>97A</td>
<td>90C</td>
<td>66 CD</td>
</tr>
<tr>
<td>L 0.36 Met+0.28 Sulf</td>
<td>99A</td>
<td>95A</td>
<td>85ABC</td>
</tr>
<tr>
<td>L 0.07 Met</td>
<td>30 C</td>
<td>23 D</td>
<td>15 E</td>
</tr>
<tr>
<td><strong>Fouke (Net Site Grasses)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E 0.15 Sulf^2</td>
<td>99A</td>
<td>99A</td>
<td>99A</td>
</tr>
<tr>
<td>E 0.28 Sulf</td>
<td>99A</td>
<td>99A</td>
<td>99A</td>
</tr>
<tr>
<td>E 0.36 Gly+0.15 Sulf</td>
<td>99A</td>
<td>99A</td>
<td>99A</td>
</tr>
<tr>
<td>E 0.36 Gly+0.28 Sulf</td>
<td>99A</td>
<td>99A</td>
<td>99A</td>
</tr>
<tr>
<td>L 0.43 Flo+0.15 Sulf</td>
<td>90</td>
<td>81C</td>
<td>63 BC</td>
</tr>
<tr>
<td>L 0.43 Flo+0.28 Sulf</td>
<td>90</td>
<td>95A</td>
<td>85AB</td>
</tr>
<tr>
<td>L 0.36 Met+0.15 Sulf</td>
<td>90</td>
<td>78 C</td>
<td>75AB</td>
</tr>
<tr>
<td>L 0.36 Met+0.28 Sulf</td>
<td>90</td>
<td>93A</td>
<td>75AB</td>
</tr>
</tbody>
</table>

1. Eearly; L-late; 
2. Sulf=metsulfuron methyl; Met=metsulfuron methyl; Gly=glysophosate; Hex=hexazinone;
3. Treatment means having the same letter within the column are not significantly different at the 0.05 level (Duncan's Multiple Range test).

Results and Discussion

Efficacy

Overall control of herbaceous competitors was good at all sites (Table 2). Treatments with 0.15 kg/ha of sulfometuron methyl alone or in mixture generally provided control similar to the high rate at a lower cost. Mixtures containing sulfometuron methyl showed little additional control over that observed for sulfometuron methyl alone. On mixed grasses, metsulfuron methyl gave narrow spectrum weed control. At Fouke, hexazinone + metsulfuron methyl proved the least effective.

At 60 to 90 DAT, bermudagrass had invaded plots from the sides regardless of timing, rate, or herbicide. Future tests on bermudagrass should include fall applications prior to spring planting, over-the-top applications with a wider band (1.7 meters), or multiple applications of herbicide. At 120 DAT herbes were re-established in all plots at all sites.

Early applications were more effective than late ones (Table 3). This may be related to differences in competitor biomass levels at application (Zutter et al., 1986) in which case lower rates may be used if herbicides are applied early (Table 4).

Seeding Response

First- and second-year survival and growth were greater at Alleene than Fouke (Table 5). This probably occurred for two reasons. First, levels of herbaceous biomass were higher at Alleene than Fouke, and thus the release was greater (Table 4). Land managers should consider site conditions, the density of herbaceous competitors and the type and timing of site preparation before recommending additional competitor control. Avoid blanket recommendations. Second, Fouke was poorly drained with water standing between beds through June. During this same period, Alleene was well drained. Excessive moisture is known to inhibit seedling development (Patrick, 1977; Stone, 1977).

Based on survival, height and groundline diameter, treatment of mixed grasses with sulfometuron methyl, hexazinone + sulfometuron methyl and sethoxydim + sulfometuron methyl were the most effective treatments (Table 5). These treatments provided first-year responses averaging 17% more survival, 59% more height, and 235% more groundline diameter. Glyphosate treatments resulted in 17% less survival, 49% less height and 6% more groundline diameter than check seedlings.

For bermudagrass control, similar and best survival and growth in height and groundline diameter were recorded on sulfometuron methyl and sethoxydim + sulfometuron methyl treated plots (Table 5). These treatments provided first-year responses averaging 6% more survival, 61% more height growth, and 210% more groundline diameter than check seedlings. During this same period, glyphosate + sulfometuron

Table 3. Mean percent control of herbaceous competitors.

<table>
<thead>
<tr>
<th>Time</th>
<th>Days After Treatment</th>
<th>Alleene (Mixed Grasses)</th>
<th>Alleene (Bermudagrass)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>30</td>
<td>60</td>
<td>90</td>
</tr>
<tr>
<td>Early</td>
<td>97A</td>
<td>96A</td>
<td>96A</td>
</tr>
<tr>
<td>Late*</td>
<td>80 B</td>
<td>67 B</td>
<td>56 B</td>
</tr>
</tbody>
</table>

1. Treatment means having the same letter within the column are not significantly different at the 0.05 level (Duncan's Multiple Range test).

Table 4. Trends in herbaceous biomass (kg/ha) on untreated plots.

<table>
<thead>
<tr>
<th>Location</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>August</th>
<th>September</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mixed Grasses</td>
<td>209</td>
<td>901</td>
<td>118</td>
<td>1721</td>
<td>1841</td>
</tr>
<tr>
<td>Bermuda-grass</td>
<td>172</td>
<td>708</td>
<td>1214</td>
<td>2345</td>
<td>2856</td>
</tr>
<tr>
<td>Wet Site Grasses</td>
<td>71</td>
<td>131</td>
<td>289</td>
<td>791</td>
<td>741</td>
</tr>
</tbody>
</table>
Survival and Growth Two Years After Control of Herbaceous Competitors in Newly Planted Seedlings of Loblolly Pine

Table 5. Mean survival (SUR), total height (HT) and groundline diameter (GLD) after one (86) and two (87) growing seasons.

<table>
<thead>
<tr>
<th>Time</th>
<th>Herbicide (kg/ha)</th>
<th>SUR (E) 86</th>
<th>BT (CM) 86</th>
<th>GLD (PO) 86</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Loblolly (Mixed Grasses)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L 0.43 Flush, 0.28 Sulf</td>
<td>98A</td>
<td>100A</td>
<td>47BC</td>
<td>138A</td>
</tr>
<tr>
<td>L 0.56 Seth, 0.28 Sulf</td>
<td>98A</td>
<td>100A</td>
<td>47BC</td>
<td>138A</td>
</tr>
<tr>
<td>L 0.15 Hex</td>
<td>98A</td>
<td>100A</td>
<td>47BC</td>
<td>138A</td>
</tr>
<tr>
<td>L 0.28 Sulf</td>
<td>98A</td>
<td>100A</td>
<td>47BC</td>
<td>138A</td>
</tr>
<tr>
<td>E 0.6 Hex, 0.15 Sulf</td>
<td>98A</td>
<td>100A</td>
<td>47BC</td>
<td>138A</td>
</tr>
<tr>
<td>E 0.56 Gly, 0.28 Sulf</td>
<td>98A</td>
<td>100A</td>
<td>47BC</td>
<td>138A</td>
</tr>
<tr>
<td>L 0.56 Sulf</td>
<td>98A</td>
<td>100A</td>
<td>47BC</td>
<td>138A</td>
</tr>
<tr>
<td>L 0.28 Sulf</td>
<td>98A</td>
<td>100A</td>
<td>47BC</td>
<td>138A</td>
</tr>
<tr>
<td>E 0.56 Hex</td>
<td>98A</td>
<td>100A</td>
<td>47BC</td>
<td>138A</td>
</tr>
<tr>
<td>E 0.56 Gly</td>
<td>98A</td>
<td>100A</td>
<td>47BC</td>
<td>138A</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Time</th>
<th>Herbicide (kg/ha)</th>
<th>SUR (E) 87</th>
<th>BT (CM) 87</th>
<th>GLD (PO) 87</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Loblolly (Bermudagrass)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L 0.43 Flush, 0.15 Sulf</td>
<td>98A</td>
<td>100A</td>
<td>47BC</td>
<td>138A</td>
</tr>
<tr>
<td>L 0.56 Seth, 0.15 Sulf</td>
<td>98A</td>
<td>100A</td>
<td>47BC</td>
<td>138A</td>
</tr>
<tr>
<td>L 0.43 Flush, 0.15 Sulf</td>
<td>98A</td>
<td>100A</td>
<td>47BC</td>
<td>138A</td>
</tr>
<tr>
<td>L 0.15 Hex</td>
<td>98A</td>
<td>100A</td>
<td>47BC</td>
<td>138A</td>
</tr>
<tr>
<td>L 0.28 Sulf</td>
<td>98A</td>
<td>100A</td>
<td>47BC</td>
<td>138A</td>
</tr>
<tr>
<td>E 0.6 Hex, 0.15 Sulf</td>
<td>98A</td>
<td>100A</td>
<td>47BC</td>
<td>138A</td>
</tr>
<tr>
<td>E 0.56 Gly, 0.28 Sulf</td>
<td>98A</td>
<td>100A</td>
<td>47BC</td>
<td>138A</td>
</tr>
<tr>
<td>L 0.56 Sulf</td>
<td>98A</td>
<td>100A</td>
<td>47BC</td>
<td>138A</td>
</tr>
<tr>
<td>L 0.28 Sulf</td>
<td>98A</td>
<td>100A</td>
<td>47BC</td>
<td>138A</td>
</tr>
<tr>
<td>E 0.56 Hex</td>
<td>98A</td>
<td>100A</td>
<td>47BC</td>
<td>138A</td>
</tr>
<tr>
<td>E 0.56 Gly</td>
<td>98A</td>
<td>100A</td>
<td>47BC</td>
<td>138A</td>
</tr>
</tbody>
</table>

These results show that total weed control does not always correlate with seedling performance. The low rate of sulfometuron methyl provided intermediate competitor control but was among treatments with the best seedling survival and growth. Metsulfuron methyl provided the worst control of mixed grasses and above average seedling survival and growth. This suggests that total control may not be needed for optimal seedling growth. Additional work is needed to determine the level of control needed for optimal seedling performance and cost effective treatments. Second, physiologically active seedlings should not be treated with mixtures of glyphosate. That is, pine tolerance can not be sacrificed to gain additional control for subsequent growth. Third, several mixtures and rates of herbicides are available for control of selected herbaceous competitors. Therefore, land managers can select herbicides based on availability, cost and the specific competitors to be controlled. Fourth, sulfometuron methyl alone or mixed with haloxyfop provided best seedling response at all three sites. Fifth, a two-year increase in survival and growth can be used to justify treatment cost. Sixth, March through April applications provided similar seedling responses giving land managers an opportunity to integrate herbaceous vegetation control with other land management practices.

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LITERATURE CITED


CONTROL OF HERBACEOUS COMPETITORS IN PROGENY TESTS USING CONTAINER-GROWN SEEDLINGS

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ABSTRACT

Container-grown and May-planted seedlings of loblolly and shortleaf pines were treated with herbicides for control of herbaceous competitors. Weed control and seedling growth were evaluated. Competitor control was good for all treatments. Survival and growth of pines differed by species and herbicide treatment. The best treatment for both species included covering seedlings and spraying competitors with glyphosate. Both species showed decreased survival and growth when treated with medium and high rates of hexazinone + sulfometuron methyl.

INTRODUCTION

Studies have reported herbicide tolerance and performance of loblolly pine (Pinus taeda L.) seedlings released from herbaceous competition with various herbicides including sulfometuron methyl, glyphosate, hexazinone, atrazine and imazapyr. Zutter (1984) showed that weed control resulted in greater height and diameter growth of loblolly pine, with trees receiving weed control for two years showing the most improvement. Barber et al. (1984) reported that imazapyr and sulfometuron methyl may cause stunting of loblolly pine. Sulfometuron methyl was found to be the most consistently effective herbicide in another study (Nelson and Metcalfe, 1983). Hexazinone caused greater pine mortality on sites with coarser soil texture when used for pine release (Minogue et al., 1984). Increases in early height growth were attributed to herbaceous weed control. Similar information on the performance of seedlings of shortleaf pine (P. echinata Mill.) is lacking. All of the above herbicides are labeled for use in herbaceous weed control in forestry in the South (Anonymous 1988).

Most studies of herbaceous competition control have addressed operational plantings of bare-root seedlings. Many of the companies expected to apply this information also participate in tree breeding programs and need similar information for container-grown seedlings used in progeny tests. Progeny tests are used to determine the efficacy of selected matings in a tree breeding program, and are maintained in a relatively artificial environment compared to operational plantings (van Buijtenen and Lowe, 1982). Such plots usually receive broadcast weed control. Progeny tests represent a substantial investment of time and money to the company, and are usually maintained at all costs.

Container-grown seedlings differ from bare-root seedlings in that they may be less than six months old, and no dormant period is experienced prior to outplanting. Seedlings are vigorous, often with little woody tissue, and are actively growing when planted in late spring after danger of frost is past. Bare-root seedlings are nearly one year old and are dormant when lifted from the nursery bed prior to planting during the winter months.

Planting methods also differ between bare-root and container-grown stock. Ordinarily, bare-root seedlings are planted by hand using a dibble with a 10 inch long spade, which often places the root collar of these seedlings several inches below ground. Container-grown seedlings have more uniform root development, and are planted using tools designed for such seedlings. While this places the tree at the appropriate position in the substrate, it also places its roots in a more vulnerable location when soil-active herbicides are applied.

The limited information on the response of shortleaf pine and container-grown seedlings to herbicide treatments and control of herbaceous competitors justifies the establishment of this study. The study objectives are: 1) to contrast the efficacy of herbicides, and 2) to compare the survival and growth of container-grown seedlings of loblolly and shortleaf pines when released from herbaceous competitors using herbicides.

MATERIALS AND METHODS

The study is near Batesville in Independence County, which is physiographically in the Ozark Highlands of northern Arkansas. The soil is a sandy loam with 62 percent sand, 34.5 percent silt, 2 percent clay and 1.5 percent organic matter.

Christmas trees were removed from the site in 1985 leaving a dense sod supporting major proportions of broomseed (Andropogon spp.), sedges (Carex spp.), and panicgrass (Panicum spp.), with lesser proportions of crabgrass (Digitaria spp.), bermudagrass (Cynodon spp.), blackberry (Rubus spp.), greenbrier (Smilax spp.), and sumac (Rhus spp.).

In mid-September, 1986, 3.2 kg/ha glyphosate was broadcast over the entire study. In November, seeds from loblolly and shortleaf pines were sown in styroblocks® (No. 8) and the seedlings were grown in a greenhouse. Two weeks before outplanting, seedlings were moved outside to become acclimated. actively growing seedlings were outplanted on May 6, 1987 on a 1.2 x 2.4 m spacing. The fall application of glyphosate plus droughty conditions over the previous year contributed to minimal early May herbaceous competition. Approximately 1.9 cm of precipitation fell shortly before and on the day of planting.

Treatments were applied in 0.9 m bands centered on seedlings. Each herbicidal treatment was mixed with water until the total volume was 93.5 l/ha. Treatments were applied in late May following 2.54 cm of postplanting precipitation. Seedlings were visible and herbaceous competitors abundant at treatment. The glyphosate treatment was scheduled as a preplant application, but lack of herbaceous vegetation resulted in delaying application until late May with the other treatments. Treatments tested are presented in Table 1.

Reduction of herbaceous competition was expressed to the nearest 5% class by visual estimation at 30 and 60 days after treatment. Following the 60-day evaluation, seedlings were covered and glyphosate (3.2 kg/ha) applied to all non-check plots in a 0.9 m band to control the regrowth of Rhus and Cynodon spp.
Control of Herbaceous Competitors in Progeny Tests Using Container-Grown Seedlings

Seedling heights (cm) and groundline diameters (mm) were recorded on planting day and again in November 1987. Seedlings were also assessed in July for mortality.

The study was a randomized block design with three blocks. Each block contained 20 one-row plots with 20 seedlings per plot. Data were evaluated using analyses of covariance (P = 0.05) with initial height or initial groundline diameter as covariates. Duncan's Multiple Range test was used to contrast means (P = 0.05).

Table 1. Herbicide treatments and efficacy.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>kg ai/ha</th>
<th>Days After Treatment</th>
<th>--</th>
<th>--</th>
</tr>
</thead>
<tbody>
<tr>
<td>L-atrazine+sulfometuron methyl</td>
<td>2.52</td>
<td>100</td>
<td>97 A</td>
<td></td>
</tr>
<tr>
<td>H-atrazine+sulfometuron methyl</td>
<td>0.85</td>
<td>98</td>
<td>98 A</td>
<td></td>
</tr>
<tr>
<td>M-atrazine+sulfometuron methyl</td>
<td>0.56</td>
<td>95</td>
<td>95 AB</td>
<td></td>
</tr>
<tr>
<td>L-hexazinone+sulfometuron methyl</td>
<td>0.26</td>
<td>95</td>
<td>95 ABC</td>
<td></td>
</tr>
<tr>
<td>H-hexazinone+sulfometuron methyl</td>
<td>0.36</td>
<td>95</td>
<td>95 ABC</td>
<td></td>
</tr>
<tr>
<td>L-imazapyr</td>
<td>0.35</td>
<td>93</td>
<td>93 ABC</td>
<td></td>
</tr>
<tr>
<td>L-sulfometuron methyl</td>
<td>0.17</td>
<td>85</td>
<td>85 CD</td>
<td></td>
</tr>
<tr>
<td>H-ATRamine+sulfometuron methyl</td>
<td>0.16</td>
<td>85</td>
<td>85 CD</td>
<td></td>
</tr>
<tr>
<td>L-ATRamine+sulfometuron methyl</td>
<td>1.10</td>
<td>90</td>
<td>88 BCB</td>
<td></td>
</tr>
<tr>
<td>Check</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 Only treatment with seedlings covered during the application of herbicide.
2 L=Low; M=Medium; H=High.
3 Means within a column sharing the same letter are not significantly different (Duncan’s Multiple Range test).

RESULTS AND DISCUSSION

The fall application of glyphosate was effective. The composition of September 1986 and May 1987 herbaceous competitors was similar, although many May competitors were new germinants. This probably contributed to the very effective and similar efficacy observed at the 30- and 60-day evaluations (Table 1). New germinants of Andropogon ssp. were controlled by imazapyr and mixtures of hexazinone. The

Table 2. Mean seedling response to herbicide treatment.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Height</th>
<th>Groundline Diameter</th>
<th>Survival</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glyphosate</td>
<td>14.5</td>
<td>2.8</td>
<td>76.0</td>
</tr>
<tr>
<td>L-atrazine+sulfometuron methyl</td>
<td>6.2</td>
<td>1.2</td>
<td>28.3</td>
</tr>
<tr>
<td>M-atrazine+sulfometuron methyl</td>
<td>6.1</td>
<td>1.2</td>
<td>36.0</td>
</tr>
<tr>
<td>H-atrazine+sulfometuron methyl</td>
<td>12.4</td>
<td>2.6</td>
<td>55.8</td>
</tr>
<tr>
<td>L-imazapyr</td>
<td>11.0</td>
<td>2.5</td>
<td>68.3</td>
</tr>
<tr>
<td>L-sulfometuron methyl</td>
<td>12.3</td>
<td>2.4</td>
<td>71.3</td>
</tr>
<tr>
<td>H-imazapyr</td>
<td>13.6</td>
<td>2.8</td>
<td>68.2</td>
</tr>
<tr>
<td>L-ATRamine+sulfometuron methyl</td>
<td>11.7</td>
<td>2.0</td>
<td>53.3</td>
</tr>
<tr>
<td>L-ATRamine+sulfometuron methyl</td>
<td>13.2</td>
<td>1.0</td>
<td>70.8</td>
</tr>
<tr>
<td>Check</td>
<td>13.5</td>
<td>1.8</td>
<td>65.0</td>
</tr>
</tbody>
</table>

1 Only treatment with seedlings covered during the application of herbicide.
2 Means within a column sharing the same letter are not significantly different (Duncan’s Multiple Range test).
3 L=Low; M=Medium; H=High.

Table 3. Response of container-grown, loblolly (Lob) and shortleaf (Shlf) pine seedlings to treatments of herbicides for herbaceous control.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Height</th>
<th>Shlf</th>
<th>Groundline Diameter</th>
<th>Shlf</th>
<th>Survival</th>
</tr>
</thead>
<tbody>
<tr>
<td>L-atrazine+sulfometuron methyl</td>
<td>18.1</td>
<td>12.2 AB*</td>
<td>3.8 A</td>
<td>2.2 A*</td>
<td>80.0</td>
</tr>
<tr>
<td>sulfometuron methyl</td>
<td>16.6</td>
<td>10.7 B*</td>
<td>3.6 A</td>
<td>2.0 A*</td>
<td>80.0</td>
</tr>
<tr>
<td>H-imazapyr</td>
<td>15.3</td>
<td>6.8 CD*</td>
<td>3.1 AB</td>
<td>2.1 A</td>
<td>75.0</td>
</tr>
<tr>
<td>Check</td>
<td>14.9</td>
<td>12.0 AB</td>
<td>2.1 CD</td>
<td>1.6 A</td>
<td>70.0</td>
</tr>
<tr>
<td>L-imazapyr</td>
<td>14.7</td>
<td>10.0 BC*</td>
<td>2.6 BCD</td>
<td>2.1 A</td>
<td>75.0</td>
</tr>
<tr>
<td>Glyphosate</td>
<td>14.0</td>
<td>15.1 A</td>
<td>3.2 AB</td>
<td>2.4 A</td>
<td>58.3 BC</td>
</tr>
<tr>
<td>L-hexazinone+sulfometuron methyl</td>
<td>14.0</td>
<td>10.8 B</td>
<td>2.8 ABC</td>
<td>2.3 A</td>
<td>56.7 BC</td>
</tr>
<tr>
<td>H-hexazinone+sulfometuron methyl</td>
<td>11.6</td>
<td>11.9 AB</td>
<td>2.0 CD</td>
<td>2.0 A</td>
<td>50.0</td>
</tr>
<tr>
<td>M-hexazinone+sulfometuron methyl</td>
<td>9.8</td>
<td>2.7 E*</td>
<td>1.9 CD</td>
<td>0.6 B*</td>
<td>41.3</td>
</tr>
<tr>
<td>M-hexazinone+sulfometuron methyl</td>
<td>8.7</td>
<td>3.6 DE*</td>
<td>1.8 D</td>
<td>0.5 B*</td>
<td>41.7</td>
</tr>
</tbody>
</table>

Species Mean 13.7A 4 9.6 B 2.7 A 1.8 B 63.0 A 53.8 B

1 L=Low; M=Medium; H=High.
2 Only treatment with seedlings covered during the application of herbicide.
3 Means within a column sharing the same letter are not significantly different (Duncan’s Multiple Range test).
4 Species means within a row sharing the same letter are not significantly different (Duncan’s Multiple Range test).
* The loblolly versus shortleaf contrast is significant (Duncan’s Multiple Range test).
July reaplication of glyphosate to treatment plots resulted in nearly total control of herbaceous competitors throughout the summer.

Seedling mortality in late July was not significantly different from that recorded in November; thus November values are presented (Table 2). Greatest survival was observed on imazapyr, check, sulfometuron methyl, glyphosate, and atrazine (low) plus sulfometuron methyl treated plots. Mixtures of hexazinone (low) or atrazine (high) with sulfometuron methyl were similar with intermediate survival while medium and high levels of hexazinone plus sulfometuron methyl were similar with the least survival. Mortality on atrazine (high) or hexazinone plus sulfometuron methyl treated plots was greater than for untreated check plots and was unacceptable.

For treatments with acceptable survival, similar and best growth was observed on plots treated with imazapyr (low), sulfometuron methyl, glyphosate (covered seedlings), and atrazine (low) mixed with sulfometuron methyl (Table 1).

Greatest survival and growth of loblolly and shortleaf pine seedlings varied by herbicide treatment (Table 3). Seedlings of loblolly pine exhibited better survival and growth than those of shortleaf pine (Table 3). Acceptable shortleaf pine survival occurred on plots treated with imazapyr (low) and glyphosate (covered seedlings). Seedlings of shortleaf pine showed lower survival and growth than loblolly pine seedlings when plots were treated with medium and high hexazinone mixtures with sulfometuron methyl, sulfometuron methyl (alone), and atrazine (low) mixed with sulfometuron methyl. Shortleaf pine height growth was also less than loblolly on imazapyr treated plots. Data suggest seedlings of shortleaf pine may be more sensitive to herbicides than seedlings of loblolly pine.

Greatest survival and growth of loblolly pine seedlings occurred on plots treated with atrazine (low) + sulfometuron methyl, sulfometuron methyl (alone), and imazapyr (high). The best treatment for both species was covering seedlings and spraying plots with glyphosate. Worst growth and survival for loblolly and shortleaf seedlings occurred with treatments containing medium to high rates of hexazinone.

ACKNOWLEDGEMENTS

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LITERATURE CITED


GENERAL NOTES

SPAWNING FREQUENCY AND FECUNDITY OF BLUE TILAPIA

Blue tilapia, *Tilapia aurea*, are becoming increasingly popular as commercial culture fish in Arkansas. Tilapia have a variety of aquaculture applications. They can be used to control rooted aquatic vegetation and filamentous algae, raised for sale as baitfish or to provide forage for channel catfish brood stock, largemouth bass or striped bass. In addition, polyculture of blue tilapia and channel catfish may result in a reduced incidence of off-flavor in channel catfish (Torrans and Lowell, Proc. Ark. Acad. Sci., 41:82-86, 1987).

Blue tilapia are also excellent food fish, however, the growing season in central Arkansas may be too short to grow them to market size in a single season (Torrans and Lowell, Proc. Annu. Conf. Southeast Assoc. Fish and Wildl. Agencies, 40:187-193, 1986). Early spawning of tilapia in a heated indoor hatchery may extend the growing season long enough to solve this problem. The purpose of this study was to determine the spawning frequency and fecundity of blue tilapia spawned in indoor facilities.

Twenty sexually mature pair of blue tilapia were placed in individual 36”-diameter circular tanks on July 15, 1982. The females ranged in weight from 22 g to 138 g and the males from 50 g to 178 g. The upper lip (maxillary and premaxillary bones) was surgically removed from the males prior to the study to reduce aggressive behavior toward the females. The fish were fed daily to satiation with a 32% protein floating feed.

The tanks were continuously supplied with outdoor pond water at ambient temperature, and the water temperature was monitored beginning the third week of the study with a recording thermometer. A 6” piece of 4” diameter PVC pipe was placed on the bottom of each tank to provide a refuge for the female. Spawning substrates, such as sand or gravel, were not added to the tanks.

The fish were examined at weekly intervals for 15 weeks. Females that had spawned and were mouthbrooding eggs were removed with a fine mesh dip net and weighed to the nearest gram. The eggs were removed from the buccal cavity for later counting, and the females were immediately returned to their respective tanks.

The 20 pair of tilapia spawned a total of 48 times during the study. Five females did not spawn, three spawned once, three spawned twice, three spawned three times, one spawned four times, four spawned five times, and one spawned six times. Twenty-three of the 33 repeat spawns came within two weeks of the previous spawn. There was not a significant correlation between female weight and spawning frequency (r = -0.25, N = 20), nor between the male/female weight ratios and spawning frequency (r = 0.15, N = 20).

![Graph 1](http://scholarworks.uark.edu/jaas/vol42/iss1/1)

**Figure 1.** Spawn size (number of eggs) of female blue tilapia. The calculated regression line is shown.

The spawns ranged in size from 97 eggs from a 24 g female, to 1042 eggs from a 117 g female (Figure 1). While there was a highly significant positive correlation between female weight and spawn size (r = 0.55, P < 0.01, N = 48), there was considerable variation in the size of the spawns produced by individual females. One female, for example, produced consecutive spawns of 178 and 479 eggs. The reason for this variation is unknown. There was no clear tendency for successive spawns to be larger, nor was there a significant correlation between the spawn size and the time period since the last spawn.

Only one fish spawned during week 4 (Figure 2), when the highest temperature of the study was recorded (29.6°C). This may indicate an upper temperature threshold for spawning. Within the temperature range of 25°C to 28°C, 20% to 35% of the females spawned each week. Spawning ceased in late September and early October (weeks 11, 14 and 15) when the weekly water temperature averaged 19.4°C or less. The lowest weekly water temperature at which fish spawned during this study was 21.1°C. This was one degree lower than the lower temperature threshold previously determined for pond spawning in the spring, when the water temperature was rising (Torrans and Lowell, Ark. Farm Research, 34[1]:3, 1985).

Indoor production of tilapia fry is possible. Tilapia will spawn readily in confinement within the optimum temperature range of 25°C to 28°C. Female tilapia can spawn in intervals as short as two weeks if they are not allowed to incubate the eggs. Eleven kg (twenty-five pounds) of female tilapia could produce over 20,000 fry per week on a continuing basis, assuming a 25% weekly spawning rate. The spawning rate, and thus total weekly egg production, could be increased if non-spawning females were identified and replaced.

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THOMAS J. AURELI, Arkansas Power and Light Company, 9005 Penrose Lane, Little Rock, AR 72205, and LES TORRANS, Department of Agriculture, University of Arkansas at Pine Bluff, Pine Bluff, AR 71601.
EQUATIONS OF VARIATION FOR ORDINARY DIFFERENTIAL EQUATIONS ON MANIFOLDS

For systems of ordinary differential equations in $\mathbb{R}^n$ (real Euclidean space of dimension $n$), it is well known that derivatives of solutions with respect to the initial time, initial position and parameters satisfy certain variational equations. However, for systems of ordinary differential equations on manifolds, only the variational equations for the derivatives of solutions with respect to the initial position seem to have appeared in print (Sternberg, Lectures on Differential Geometry, p. 184, 1964). In this paper, we will derive equations of variation for systems on manifolds. Our methods are different from those employed in the above reference and since no extra effort is involved, all three types will be deduced.

For definitions and properties concerning differentiable manifolds, we refer the reader to (Brickell and Clark, Differentiable Manifolds, 1970).

We consider the initial value problem

$$\frac{d}{dt} f_j = X(u) o (i d U^{-1} \times V^{-1}) = X(u) o (i d U^{-1} \times V^{-1})$$

and set $f = (f_1, ..., f_m)$.

Arguments similar to those given in (Brickell and Clark, Differentiable Manifolds, p. 131, 1970) establish that $c: 1 \rightarrow M$ is a solution of (IV) if and only if $uoc$, restricted to $J$, is a solution of

$$c(t) = X(u(t), v(t)), c(t_0) = u_0.$$  

Denote the value of this solution at $t$ by $z(t)$, its restriction to $J$, by $z(t)$, if $t$ is in $J$ and $J$ is contained in $(t_0, t_1)$. Then $z(t)$ implies $(c(t), q)$ is in $dom(X)$. For $j = 1, ..., m$, let $u_j$ be the $j$th coordinate function of $u$ and let $X_{u_j}(t)$ be the value of the vector field, $X$, at $u_j$. Also, define $f_j$ by

$$f_j = X(u) o (i d U^{-1} \times V^{-1}) = X(u) o (i d U^{-1} \times V^{-1})$$

Thus, $z = uoc(didxu^{-1} dV^{-1})$, and it follows that $z$ is $C^\infty$. Also, $f$ is $C^\infty$ because we assumed that $X$ is $C^\infty$.

For the purpose of writing partial derivatives, we will denote the arguments of $Z$ by $(t, t_0, x)$ where $x = (x_1, ..., x_m)$ and $t = (t_0, ..., t_1)$. It is well known (Reid, Ordinary Differential Equations, p. 70, 1971) that the first partial derivatives of $Z$ with respect to $t_0$, $\xi$, and $\eta$ satisfy certain variational equations. In the equations that follow, it is understood that the arguments of derivatives of the $Z_j$ are $(t, t_0, u(p), v(q))$ and the arguments of derivatives of the $f_j$ are $(t, t_0, u(p), v(q))$. Also, $\delta_j$ denotes the Kronecker delta. The variational equations are

$$\frac{d}{dt} \frac{\partial z_j}{\partial t_0} = \frac{\partial f_j}{\partial t_0} (t, t_0, u(p), v(q)) = f_j (t, t_0, u(p), v(q));$$

$$\frac{d}{dt} \frac{\partial z_j}{\partial t_1} = \frac{\partial f_j}{\partial t_1} (t, t_0, u(p), v(q)) = \delta_j;$$

$$\frac{d}{dt} \frac{\partial z_j}{\partial \eta_k} = \frac{\partial f_j}{\partial \eta_k} (t, t_0, u(p), v(q)) = 0.$$

It follows from (1) and (2) that $\frac{\partial z_j}{\partial t_0}$ and $\frac{\partial z_j}{\partial t_1}$ are the respective coordinate expressions for $\frac{\partial C_j}{\partial t_0}$ and $\frac{\partial C_j}{\partial t_1}$. The derivatives of the $Z_j$ are evaluated at $(t, t_0, u(p), v(q))$ and the derivatives of the $C_j$'s are evaluated at $(t, t_0, p, q)$. Also, $\frac{\partial z_j}{\partial \eta_k}$ and $\frac{\partial z_j}{\partial \eta_k}$ are coordinate expressions for $\frac{\partial X(u_j)}{\partial \eta_k}$ and $\frac{\partial X(u_j)}{\partial \eta_k}$, respectively. The derivatives of the $f_j$'s are evaluated at $(t, Z(t, t_0, u(p), v(q)), v(q))$ and the derivatives of the $X(u_j)$'s are evaluated at $(t, C(t, p, q), q)$. Consequently, the variational equations for $C$ may be found by substituting in (V1), (V2) and (V3). In the equations that follow,
it is understood that the arguments of derivatives of the $C_j'$s are $(t, t_0, p, q)$ and the arguments for the derivatives of the $X(u_j)$'s are $(t, C(t, t_0, p, q), q)$. The variational equations for the system on the manifold are

\[ \begin{align*}
\frac{\partial}{\partial t} \left( \frac{\partial C_j}{\partial t_0} \right) & = \sum_{j=1}^m \frac{\partial X(u_j)}{\partial u_j} \frac{\partial C_j}{\partial t} \quad \frac{\partial C_j}{\partial t} (t, t_0, p, q) = X(u_j)(t, t_0, p, q); \\
\frac{\partial}{\partial t} \left( \frac{\partial C_j}{\partial u_k} \right) & = \sum_{j=1}^m \frac{\partial X(u_j)}{\partial u_k} \frac{\partial C_j}{\partial t} \quad \frac{\partial C_j}{\partial u_k} (t, t_0, p, q) = \delta_{jk} \\
\frac{\partial}{\partial t} \left( \frac{\partial C_j}{\partial v_k} \right) & = \sum_{j=1}^m \frac{\partial X(u_j)}{\partial v_k} \frac{\partial C_j}{\partial t} + \frac{\partial X(u_j)}{\partial v_k} \frac{\partial C_j}{\partial v_k} \quad \frac{\partial C_j}{\partial v_k} (t, t_0, p, q) = 0. 
\end{align*} \]

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NOTES ON THE BIOLOGY OF THYANTA CALCEATA (HEMIPTERA: PENTATOMIDAE) ON TEPHROSIA VIRGINIANA (LEGUMINOSAE), A NEW HOST PLANT

_Thyanta calceata_ (Say) is distributed over the eastern United States from New England to Florida and west to Michigan, Illinois and Missouri (McPherson, The Pentatomoidea [Hemiptera] of northeastern North America with emphasis on the fauna of Illinois. S. Ill. Univ. Pr., Carbondale, 1982). The nymphal instars of this pentatomid have been previously described (Paskewitz and McPherson, Great Lakes Entomol. 15(4):231-255, 1982). _Tephrosia virginiana_ (L.) ranges from Massachusetts south to Georgia, and west to Minnesota, Texas and Oklahoma (Steyermark, Flora of Missouri, Iowa St. Univ. Pr., Ames, 1975). This study presents additional information on the biology of this insect as it relates to _T. virginiana_, a previously unreported host plant.

McPherson (1982) reported _T. calceata_ having been collected from soybean, red clover, blue-grass, cheat, wheat, winter cress, milkweed, horse-weed, buckbrush, _Lespedeza_, bean, pea, tomato, allegheny blackberry, common bronegrass, mullein, wild raspberry, goldenrod, and evening primrose. We have observed _T. calceata_ commonly associated with _T. virginiana_ in northeastern Arkansas on Crowley's Ridge and in northern Arkansas and southern Missouri on the Ozark Plateau.

Table 1. Occurrence of _Thyanta calceata_ on _Tephrosia virginiana_, 28 April - 7 August 1987.

<table>
<thead>
<tr>
<th></th>
<th>PREBLOOM</th>
<th>FLOWERING</th>
<th>POSTBLOOM</th>
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<td>April</td>
<td>28</td>
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<tr>
<td>May</td>
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<tr>
<td>August</td>
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Adult (N=23)  1  3  6  3  2  1  1  4  2

1st Instar (N=0)

2nd Instar (N=7)  1  1  1  1  2

3rd Instar  2  1

4th Instar (N=7)  1  2  2  1  2  1

5th Instar (N=1)  1

McPherson (1982) reported _T. calceata_ having been collected from soybean, red clover, blue-grass, cheat, wheat, winter cress, milkweed, horse-weed, buckbrush, _Lespedeza_, bean, pea, tomato, allegheny blackberry, common bronegrass, mullein, wild raspberry, goldenrod, and evening primrose. We have observed _T. calceata_ commonly associated with _T. virginiana_ in northeastern Arkansas on Crowley's Ridge and in northern Arkansas and southern Missouri on the Ozark Plateau.

Table 1. Occurrence of _Thyanta calceata_ on _Tephrosia virginiana_, 28 April - 7 August 1987.
REPRODUCTIVE CHARACTERISTICS OF SOUTH FLORIDA STERNOTHERUS ODORATUS AND KINOSTERNON BAURII (TESTUDINES: KINOSTERNIDAE)

The reproductive characteristics of south Florida kinosternids are poorly known; however, populations of the stinkpot, Sternotherus odoratus, in central (Gross, 1982) and north Florida (Iverson, 1977), and the striped mud turtle, Kinosternon baurii, in central (Einem, 1956; Lardie, 1975) and in north Florida (Iverson, 1977, 1979) have been studied. A comparative study of northern and southern United States populations of S. odoratus by Tinkle (1961) concluded that clutch size increases with increasing body size of the female. In addition, southern populations should produce multiple clutches and exhibit both early maturity and sexual dimorphism in size. These findings were later supported by Gibbons (1970) in central Florida. The objectives of this study are to provide information on the reproductive characteristics of S. odoratus and Kinosternon baurii from south Florida and to test Tinkle's (1961) summary of southern populations of S. odoratus from a region further south than his north Florida sample.

Fifty-four turtles were collected along 1 km of Snapper Creek channel between SW 87 Ave and US Hwy 1, and along 0.3 km of C-100A canal near 104th Str. and SW 82 Ave in Miami, Dade County, Florida, from June through August 1982. Specimens were captured by dipnet or wire mesh funnel traps (1.8 × 0.8 m and 0.8 × 0.5 m) baited with bread, fish and beef scraps. Carapace length (CL) and plastron length (PL) were measured to the nearest 0.1 mm. Females were considered mature if they possessed ovarian follicles exceeding 7 mm diameter or if oviducal eggs or corpora lutea were present (Iverson, 1979). Clutch size was estimated by counts of oviducal eggs, corpora lutea, or enlarged follicles over 11 mm for S. odoratus (Iverson, 1977) and 10 mm for K. baurii (Iverson, 1979). The presence of sperm in testes was used to determine maturity in males. All turtles were deposited in the National Museum of Natural History, Washington, DC. Means are followed by ± one standard deviation. All measurements are in mm.

Sternotherus odoratus — Average carapace lengths for eighteen sexually mature females (77 ± 5.69; range = 52-80) and ten sexually mature males (68 ± 8.79; range = 62-86) support Tinkle's (1961) findings of sexual dimorphism in southern populations. This, however, was not observed by Tinkle (1961) in northern specimens. The small size at maturity in both males and females from south Florida is similar to those findings reported by Tinkle (1961) and Gibbons (1970) of 54, 61 and 52.65, respectively. These data reveal an almost continuous north to south decrease in minimum size at maturity in Florida stinkpots. Mean clutch size was not significantly different (p > 0.05) whether by counts of enlarged follicles (2.22 ± 0.44) N = 9), oviducal eggs (2.38 ± 0.51; N = 8), or corpora lutea (2.34 ± 0.76; N = 18). Based on oviducal eggs, clutch size was significantly larger (t = 2.13; p < 0.05) than the mean (1.74) reported by Gross (1982) in central Florida and significantly smaller (t = 2.87; p < 0.05) than the mean (3.2) in north Florida (Iverson, 1977). Clutch size, based on either corpora lutea (r = 0.198) or oviducal eggs (r = 0.178) showed no significant positive correlation with female plastron size at 0.05 level. Multiple sets of corpora lutea (largest first) followed by oviducal eggs found in nine female S. odoratus were 2.2 and 2 eggs (71 mmPL), 2.2 and 2 eggs (76 mmPL), 2.2 and 2 eggs (75 mmPL), 2.2 and 2 eggs (80 mmPL), 2.3 and 2 eggs (81 mmPL), and 2.2 and 2 eggs (85 mmPL). Pre-ovulatory follicles greater than 10 mm were found in all but the last three turtles. Three clutches are clearly produced by some turtles, however, production of four clutches by one female indicates that at least nine eggs are produced annually by south Florida stinkpots. Mean egg size for 19 oviducal eggs from eight females examined was 22.59 ± 2.10 (longest diameter; range = 20.0-29.0) by 13.63 ± 0.8 (shortest diameter; range = 12.2-15.0) and was not significantly correlated with female plastron size (r = 0.142; p > 0.05). It is unclear whether the absence of any significant positive correlation between clutch size and female plastron size of south Florida stinkpots reflects an artifact of a small sample, a geographic trend, or even local habitat differences. Although this sample was collected from a region further south than Tinkle's (1961), the presence of sexual dimorphism, early maturity, and multiple clutches from south Florida specimens corroborates Tinkle's (1961) summary of southern populations.

Kinosternon baurii — Average carapace lengths of fourteen sexually mature females (105 ± 10.0; range = 85-125) and twelve sexually mature males (91 ± 4.97; range = 90-98) indicates sexual dimorphism in size. Difference in mean clutch size for this sample was not significant whether estimated by counts of enlarged follicles (2.91 ± 1.75; N = 12), oviducal eggs (3.14 ± 1.67; N = 7), or corpora lutea (2.70 ± 1.43; N = 13). No significant difference in clutch size was found when compared to the 2.6 average in north Florida (Iverson, 1979). Multiple sets of corpora lutea (largest first) and oviducal eggs found in three turtles were 5, 3, and 5 eggs (102 mmPL), 3, and 3 eggs (95 mmPL). Pre-ovulatory follicles greater than 10 mm were found in all three specimens. Egg retention is suspected in one turtle (109 mmPL) that contained two corpora lutea (5.7 and 5.3 mm) and one oviducal egg. Clutch size, based either on corpora lutea (r = 0.253; p > 0.05) or oviducal eggs (r = -0.321; p < 0.05) was not significantly correlated with plastron size. These data suggest that at least nine eggs are produced from at least three clutches. Mean egg size for 22 oviducal eggs from seven females examined was 27.57 ± 1.63 (longest diameter; range = 25.0-31.0) by 13.30 ± 1.40 (shortest diameter; range = 11.7-17.3) and egg length was significantly correlated with female plastron size (r = 0.816; p < 0.05). No such correlation was found in north Florida (Iverson, 1979) using a larger sample.

The absence of initial conditions of this study limiting the capacity to play a role in multiple clutching and aseasonal reproduction in turtles (Moll and Legler, 1971); however, the scarcity of available information concerning south Florida populations as well as the diversity of suitable habitats stresses the need for further studies before possible trends in the reproductive biology of south Florida kinosternids can be established.

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LITERATURE CITED


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MEASUREMENTS OF THE DRAG ON SPHERES FALLING THROUGH THE AIR

A problem often investigated in undergraduate labs on classical mechanics is the effect of air resistance on falling objects. One of the most interesting of these involves the drag force on spheres falling through the air. Frequently in these experiments the time of fall of the sphere is measured; this time is then used in a drag equation to calculate the distance fallen, for comparison with the measured distance. This distance measurement is a critical one and, for distances on the order of a few meters or less, must be accurate to within 0.5 mm. Measurements to this precision are difficult with the equipment and techniques available to the average undergraduate laboratory, and, when several distances are involved, can present a large source of error. The experiment to be described eliminates the need for this distance measurement by using a phototransistor timer circuit to obtain the velocities at various times of flight. These measured velocities are then compared to the velocities calculated from a drag equation.

For many problems in fluid mechanics it is useful to define the dimensionless drag coefficient $C_d$ in terms of the drag force $F_d$ by the equation $C_d = (F_d/A)/(\frac{1}{2} \rho V^2)$, where $A$ is the cross sectional area of the body normal to the direction of motion, $\rho$ is the density of the medium, and $V$ is the speed of the body. Thus, for a sphere falling through the air, $F_d = \frac{1}{2} \pi \rho r^2 V^2$, where $r$ is the radius of the sphere. Another dimensionless quantity which relates the inertial forces on a body to the viscous forces is the Reynolds number $Re$ which is defined by $Re = \frac{2 \rho V r}{\eta}$, where $\eta$ is the kinematic viscosity of the medium. For spheres, the relationship between $C_d$ and $Re$ is well known from experiment; a value of $C_d = \frac{1}{2}$ for $Re$ between 100 and 1000 is commonly accepted (H. Rouse, *Elementary Mechanics of Fluids*, Dover Publishing, 1978, p. 249). For air at room temperature, $\eta = 0.15 \text{ cm}^2/\text{s}$, and for a sphere of radius $r = 2 \text{ cm}$, this range corresponds to velocities between 38 cm/s and 3800 cm/s. Since all velocity measurements in this experiment are made in this range, the drag force may be approximated by:

$$F_d = \frac{1}{4} \pi r^2 \rho_a V^2.$$  

From Newton's 2nd Law,

$$M \frac{dV}{dt} = Mg - F_d = Mg - \frac{1}{2} \pi r^2 \rho_a V^2,$$

and

$$\frac{dV}{dt} = g - \left( \frac{1}{4} \pi r^2 \rho_a V^2 \right) / \left( \frac{1}{3} \pi r^3 \rho_s \right),$$

with $\rho_s$ = the density of the sphere, so that

$$\frac{dV}{dt} = g \left( 1 - \frac{3 \rho_a V^2}{16 \rho_s \pi r^3} \right) = g \left( 1 - \frac{V^2}{V_0^2} \right),$$

where $V_0^2 = (16 \rho_s \pi r^3)/(3 \rho_a)$. From this we find

$$\frac{dV}{V_0^2 - V^2} = \frac{g \frac{dt}{V_0^2}}{V_0^2}.$$

Integrating both sides and setting $V = 0$ at $t = 0$, we have

$$\frac{1}{V_0} \tanh^{-1} \left( V/V_0 \right) = gt/V_0^2,$$

and

$$\tanh^{-1} \left( V/V_0 \right) = gt/V_0.$$

With this approximation the velocity of a sphere falling through air is given by

$$V = V_0 \left( \tanh \left( gt/V_0 \right) \right).$$

The device used for dropping the spheres was constructed by modifying the apparatus used in a typical undergraduate falling body lab. An electromagnet is mounted on a stand approximately 1.7 meters tall. Positioned in front of the magnet is a bracket designed to hold the ball before it drops without influencing its motion when it is released. The ball is held against the bracket by a metal bar which is hinged to the stand under tension by a spring, and held in place by the electromagnet. Timing was done with a Merlan Micro Series Computer #30M100 controlled by a Commodore CBM Model 8032 Computer. A double pole-single throw switch is used to control the electromagnet as well as the timer.
the switch is thrown, the power to the magnet is cut off, allowing the bar to fall and release the ball. At the same time, the timer cycle begins. Located in the path of the ball is a photogate consisting of a laser beam directed onto a phototransistor connected to the timing system. When the ball breaks the beam, the phototransistor is turned off and the timer stops. In addition, the computer can be set to measure the time the phototransistor is obstructed by the sphere. In this mode, a microsecond timer begins when the leading edge of the sphere breaks the beam and ends when the phototransistor is no longer darkened.

The experiment was conducted using a plastic sphere of diameter $d = 4.379$ cm and mass $M = 57.80$ g. Since a photogate may not be obstructed by all of an object which passes through it, a preliminary test was made and the effective diameter of the sphere was found to be 4.27 cm. The main timing procedure involved first setting the timer to the microsecond time-through-gate mode and determining the time taken for the ball to travel through the photogate. Great care was taken through numerous horizontal adjustments of the photogate system to insure that the sphere passed through the beam along its diameter, since this path will give the longest possible time measurement for the pass through the gate. When this time was achieved consistently, it was recorded as the gate time and the timer was reset to the (millisecond) time-of-flight mode. The ball was then dropped to determine the time taken to fall from rest to the photogate. This entire procedure was followed for 10 different heights at approximately 15 cm increments.

The average velocity of an object travelling a distance $d$ in a time $t$ can be written as $V = \frac{d}{t}$. If the velocity increases linearly with time, then the average velocity is equal to the velocity at $t/2$. For the time interval during which the sphere passes through the gate, the acceleration is very nearly constant, so these approximations are valid for calculating the velocity at a particular time. Thus, the experimental velocity, which is just the average velocity of the sphere through the photogate, may be calculated from 4.27 cm/(gate time) and corresponds to a total travel time equal to the time of flight plus one half the gate time. Using this travel time, the theoretical velocity was calculated from the drag equation (Eq. 8). A value for $g$ for the local latitude and elevation equal to 979.7 cm/s$^2$ and an air density of $\rho = 1.2 \times 10^{-3}$ g/cm$^3$ were used. A computer program was written to determine the lag time between the start of the timer and the actual dropping of the sphere to obtain the best agreement between the theoretical and calculated velocities; the lag was found to be 3 msec. The velocity if there were no air resistance is referred to as the ideal velocity and can be calculated from $V = gt$. Figure 1 shows the differences from the ideal case for the measured velocities and the velocities calculated from Eq. 8 for various times of flight. It is seen from the figure that the experimental velocities correspond very well with the calculated velocities.

We have shown that this timing technique can be used to provide measurements of the effects of drag forces on falling bodies to relatively high precision. This can be useful in the undergraduate laboratory to supplement the usual free-fall measurement of the gravitational acceleration and to introduce the concept of drag forces in viscous media.

J. G. ROSS, S. R. ADDISON, and N. O. GAISER, Physics Department, University of Central Arkansas, Conway, Arkansas 72032.

### Table 1. Velocities of falling spheres at various fall times.

<table>
<thead>
<tr>
<th>Time of fall (msec)</th>
<th>Ideal Velocity (cm/s)</th>
<th>Calculated Velocity (cm/s)</th>
<th>Measured Velocity (cm/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>146</td>
<td>142.97</td>
<td>142.89</td>
<td>142.95</td>
</tr>
<tr>
<td>236</td>
<td>231.46</td>
<td>231.13</td>
<td>230.73</td>
</tr>
<tr>
<td>278</td>
<td>272.21</td>
<td>271.67</td>
<td>271.98</td>
</tr>
<tr>
<td>324</td>
<td>317.17</td>
<td>316.33</td>
<td>316.50</td>
</tr>
<tr>
<td>370</td>
<td>362.41</td>
<td>361.15</td>
<td>360.80</td>
</tr>
<tr>
<td>406</td>
<td>398.14</td>
<td>396.47</td>
<td>396.23</td>
</tr>
<tr>
<td>455</td>
<td>445.58</td>
<td>443.24</td>
<td>443.58</td>
</tr>
<tr>
<td>484</td>
<td>473.72</td>
<td>470.91</td>
<td>470.57</td>
</tr>
<tr>
<td>515</td>
<td>504.80</td>
<td>501.40</td>
<td>501.06</td>
</tr>
<tr>
<td>551</td>
<td>539.80</td>
<td>535.65</td>
<td>535.77</td>
</tr>
</tbody>
</table>

The Ruby-throated Hummingbird (*Archilochus colubris*) is the only species of hummingbird known to nest in Arkansas or anywhere else in eastern North America (James and Neal, 1986; A.O.U., 1983). Until 1985 it was the only hummingbird species ever identified in Arkansas, where it is a common summer resident and migrant in all parts of the state (James and Neal, 1986).

Before 1985 there were several well documented Arkansas reports (notably at Little Rock in December of 1978 and January of 1979 and at North Little Rock in October of 1984) of unidentified hummingbirds that clearly belonged to other species (Arkansas Audubon Society files). All these were identified as members of the genus *Selasphorus*, most likely Rufous Hummingbirds (*S. rufus*), a western species that normally winters in Mexico, though small numbers of Rufous Hummingbirds regularly overwinter along the Gulf Coast of the U.S. (A.O.U., 1983). Positive identification of the Arkansas birds could not be made on the basis of field observations or photographs. Only in the plumage of the adult male (with an all-rufous back) is *S. rufus* distinguishable in the field from the very similar Allen's Hummingbird (*S. sasin*). In female and immature plumages,
the two species can be distinguished only by capturing the birds and measuring reticels (Stiles, 1972; N.L. Newfield, pers. com.). None of these early Arkansas vagrants were in adult male plumage (AAS files).

On 23 January 1985, a dead hummingbird was found frozen on its perch at Pine Bluff. Foti sent the specimen to Louisiana State University at Baton Rouge (James and Neal, 1986), where J. Van Remsen identified it as a Rufous Hummingbird and retained it in the collection (Louisiana State University Museum of Zoology, Cat. No. 121495). Other female and immature hummingbirds of the brown-and-green Selasphorus type continue to appear in Arkansas (Table 1), but have not been captured and thus, unless found dead, cannot be identified to species with certainty.

The second species of straggler hummingbird identified in Arkansas was the most surprising to date: the Green Violet-ear (Colibri thalassinus). Unlike the Rufous Hummingbird and other hummingbird species (see below) that have strayed into Arkansas, the Green Violet-ear does not occur north of Mexico except as an extremely rare vagrant. All previous verified U.S. records of the Green Violet-ear came from south-central and southern Texas (A.O.U., 1983). (Two reports from California [including the one cited in A.O.U., 1983] were rejected by the California Bird Records Committee [Roberson, 1986].) The Arkansas record for Green Violet-ear is based on a photograph taken at Fort Smith by William Brazelton on 7 October 1984. The bird itself was positively identified from photographs by the method described in James and Neal (1986).

The late summer, fall, and winter of 1987-88 yielded several hummingbirds from the West, including two species previously unrecorded from Arkansas. A hummingbird observed and photographed (Helen and Max Parker, et al.) at North Little Rock in December and January proved to be an immature male Black-chinned Hummingbird (Archilochus alexandri), a species new to the state (report accepted by the Arkansas Bird Records Committee on the basis of written documentation and photographs submitted). More surprisingly, a bird observed and photographed (also by the Parkers and others) at Gillett in January and February of 1988 was an Anna’s Hummingbird (Calypte anna) (identification verified from photographic slides in a letter from J. Van Remsen and Peter E. Scott to Max Parker, dated 11 February 1988). Anna’s Hummingbird is a species of the West Coast and Arizona reported only a few times from southern Louisiana in winter, whereas the Black-chinned, breeding as close to Arkansas as central Texas (A.O.U., 1983), having summered and possibly nested near Oklahoma City, Oklahoma (Vacin, 1969), and wintering with some regularity in southern Louisiana (N.L. Newfield, pers. com.), was almost to be expected.

Other vagrant and out-of-season hummingbirds reported in the 1987-88 season are listed in Table 1. (An island of records for extralimital birds in all Table 1. Additional vagrant and out-of-season hummingbirds 1987-88 (from Arkansas Audubon Society files).

<table>
<thead>
<tr>
<th>DATE</th>
<th>LOCATION</th>
<th>RECORD</th>
<th>OBSERVERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>26-30 Aug.</td>
<td>Fayetteville</td>
<td>Selasphorus sp.</td>
<td>Tess Grasswitz, James, Neal, &amp; others</td>
</tr>
<tr>
<td>26 Nov.</td>
<td>Fort Smith</td>
<td>Rufous (adult male)</td>
<td>William Brazelton</td>
</tr>
<tr>
<td>Dec.-Jan.</td>
<td>Little Rock</td>
<td>Archilochus sp.</td>
<td>Marge &amp; Ben Dunn, Shepherd, &amp; others</td>
</tr>
</tbody>
</table>

the increase in artificial feeding of hummingbirds is the greatly increased popularity of hummingbird feeders. We do not claim to demonstrate that this is a factor, but want to set out the hypothesis for others to test if they wish. Neither can the increase in artificial feeding of hummingbirds be demonstrated statistically; but Shepherd’s personal experience illustrates how much more common such feeding has
General Notes

become. Forty years ago Shepherd had been feeding hummingbirds from tiny glass medicine vials painted red with fingernail polish. Then he talked his father into mail-ordering from Massachusetts some hand-blown glass feeders that held about 12 cc. of sugar water each. Everybody who knew him then remembers this, because at the time, they knew no one else in Pine Bluff, Arkansas, who fed hummingbirds.

In January of this year Shepherd bought a plastic hummingbird feeder from a Little Rock florist. In mid-winter that one shop had in stock at least four models of hummingbird feeders of various designs and capacities. It is no longer unusual to see a hummingbird feeder in an Arkansas garden. There must be thousands of them! Significantly, every one of the hummingbirds seen in Arkansas during the winter months and every one identified as something other than a Ruby-throated Hummingbird was frequenting a feeder (AAS files). Not only are hummingbirds easier to see well (and thus to identify to species) when they drink repeatedly from a feeder placed near a window, but, more important for the bird, a well stockeded feeder represents the only chance for a belated hummingbird to survive more than a day or two. A hard freeze kills the last nectar-producing flowers and, along with them, any flying insects and flower-dwelling arthropods that may have been supplementing the diet of nectar.

This paper has benefited greatly from thoughtful comments offered by A. Marguerite Baumgartner, Nancy L. Newfield, and Charles R. Preston, who reviewed earlier versions of it. We thank them sincerely.

LITERATURE CITED


WILLIAM SHEPHERD, JOSEPH NEAL, THOMAS FOTT, and DOUGLAS JAMES; 'Arkansas Natural Heritage Commission, Suite 200, The Heritage Center, 225 East Markham, Little Rock, AR 72201; 'Department of Zoology, University of Arkansas, Fayetteville, Arkansas 72701.

MAMMALIAN SPECIES RECOVERED FROM A STUDY OF BARN OWL, TYTO ALBA, PELLETS FROM SOUTHWESTERN ARKANSAS

The barn owl, Tyto alba, has been historically a common raptor in Arkansas and one might expect a wealth of data available on the food habits of this owl. While studies have been conducted in other areas of the country (Banks, R. C., Auk 82:506, 1965; Jemison, E. S. and R. S. Chabreck, Wilson Bull. 74(1):95-96, 1962; and Parmalee, P. W., Auk 71:469-470, 1954), in Arkansas only one other study has been reported (Paige, K. N., C. T. McAllister, and C. R. Tumlison, Proc. Ark. Acad. Sci. 33:88-89, 1979).

A. C. Bent (1937), in his book Life Histories of North American Birds Of Prey, relates that the barn owl is a very beneficial predator in that it consumes large numbers of harmful rodents. He also indicates that its choice of prey is dependent upon those items available in its forage range.

Our study began in April 1987, when an owl roost was discovered in an abandoned cotton gin in Ozan, Hempstead County. The roost is located on the edge of a small community in an area composed mostly of farm land with scattered stands of hardwood trees.

Table 1. Frequency of occurrence (Percentage of occurrence) of prey items recovered from barn owl pellets.

<table>
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</tr>
</thead>
<tbody>
<tr>
<td>Microtus pinetorum</td>
<td>6(33.3)</td>
<td>37(54.4)</td>
<td>36(53.0)</td>
<td>6(19.4)</td>
<td>2(20.0)</td>
<td>1(11.1)</td>
<td>2(10.0)</td>
<td>2(9.1)</td>
<td>5(18.5)</td>
<td>16(62.0)</td>
<td>49(60.5)</td>
<td>162(40.1)</td>
</tr>
<tr>
<td>Sigmodon hudsonius</td>
<td>8(44.4)</td>
<td>19(27.9)</td>
<td>16(23.5)</td>
<td>16(51.6)</td>
<td>5(50.0)</td>
<td>8(88.9)</td>
<td>15(75.0)</td>
<td>16(72.7)</td>
<td>17(63.0)</td>
<td>14(28.0)</td>
<td>11(31.6)</td>
<td>145(35.9)</td>
</tr>
<tr>
<td>Rattus norvegicus</td>
<td>2(27.3)</td>
<td>10(14.7)</td>
<td>5(8.1)</td>
<td>1(1.4)</td>
<td>1(1.4)</td>
<td>1(1.4)</td>
<td>1(1.4)</td>
<td>1(1.4)</td>
<td>1(1.4)</td>
<td>1(1.4)</td>
<td>1(1.4)</td>
<td>1(1.4)</td>
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<tr>
<td>Orcypus pyrrhopus</td>
<td>3(16.7)</td>
<td>1(1.4)</td>
<td>1(1.4)</td>
<td>1(1.4)</td>
<td>1(1.4)</td>
<td>1(1.4)</td>
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<td>1(1.4)</td>
<td>1(1.4)</td>
<td>1(1.4)</td>
<td>24(5.9)</td>
</tr>
<tr>
<td>Reithrodotomys fulvescens</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2(2.9)</td>
<td>-</td>
<td>-</td>
<td>1(4.5)</td>
<td>4(8.0)</td>
<td>4(8.0)</td>
<td>-</td>
<td>-</td>
<td>24(5.9)</td>
</tr>
<tr>
<td>Reithrodotomys spectabilis</td>
<td>1(5.6)</td>
<td>-</td>
<td>-</td>
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<td>-</td>
<td>-</td>
<td>2(4.0)</td>
<td>1(1.2)</td>
<td>-</td>
<td>-</td>
<td>4(1.0)</td>
</tr>
<tr>
<td>Blarinidae</td>
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<tr>
<td>Cryptotis carolinensis</td>
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<td>-</td>
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<tr>
<td>Cryptotis parva</td>
<td>-</td>
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<td>-</td>
<td>-</td>
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<td>-</td>
</tr>
<tr>
<td>Notiosorex crassidens</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<td>-</td>
</tr>
<tr>
<td>Ochotona princeps</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Mus musculus</td>
<td>1(2.0)</td>
<td>4(4.9)</td>
<td>10(2.8)</td>
<td>1(2.0)</td>
<td>2(2.5)</td>
<td>4(1.0)</td>
<td>1(2.0)</td>
<td>2(2.5)</td>
<td>4(1.0)</td>
<td>1(2.0)</td>
<td>2(2.5)</td>
<td>4(1.0)</td>
</tr>
<tr>
<td>Total</td>
<td>18</td>
<td>68</td>
<td>68</td>
<td>31</td>
<td>10</td>
<td>9</td>
<td>20</td>
<td>22</td>
<td>27</td>
<td>50</td>
<td>81</td>
<td>404</td>
</tr>
</tbody>
</table>

Published by Arkansas Academy of Science, 1988
Initially, an area of concrete floor approximately 72 sq m was cleared of all soil, litter and remains. The process involved removing and transporting to the laboratory approximately 1500 lbs (680 kg) of material for a later study (not reported here). This bulk material constituted an initial qualitative sample of prey items. From this cleared area, during the first week of each month, quantitative samples were collected. All pellets and other remains deposited in the cleared area were collected and shipped to Arkansas State University. Once at ASU, the pellets were dried and carefully dissected and the contents identified using cranial and dental morphology. Specimens were then tagged, cataloged and permanently deposited in the Museum of Recent Mammals at ASU.

Eleven months of quantitative samples were available for this study. Analysis of these samples yielded 404 specimens comprising eleven species of mammals (9 additional specimens identified as avian were not considered in this report). The results are presented in Table 1.

Interestingly, for every month Microtus pinetorum and Sigmodon hispidus were the most numerous prey items taken. M. pinetorum was taken in greatest numbers during the months of June, July, February and March. The dominance of these two species in the pellets indicates (as do the Reithrodontomys taken) that the owl(s) at this site forage(s) extensively over the prairie-like fields north and east of the cotton gin. It appears that the owl(s) forage(s) little, if at all, within the town of Ozan.

Another interesting feature of the data is the marked increase in the number of specimens taken during June, July, February and March. The large number of items, as well as the greater diversity of prey items, taken during summer months is attributable to the fact that young were present in the roost increasing the need for food during this period. The increased number and diversity of prey taken during the month of March likely is attributable to greater activity of the prey in response to the improved weather of early spring. February's increase is likely attributable to the documented unseasonably warm weather this particular year which probably increased the nocturnal activity and therefore the availability of these prey species.

This study has resulted in the collection of eleven mammalian county records, one of which (Notiosorex crawfordi) represents a significant extension of the presently reported range. With the exception of the range extension, all of the species collected during this study have reported ranges which include this county; however, Reithrodontomys fulvescens is the only species encountered that does not represent a new documented species for Hempstead County. Notiosorex crawfordi was collected from the roost on two different occasions, indicating that this species is not simply a spurious report for Hempstead County. Previously the only known specimens of Notiosorex crawfordi were from extreme northwest Arkansas (Sealander, J. A., A Guide to Arkansas Mammals, p. 48, 1969). Our records place this species a considerable distance south and/or east of its previously acknowledged range.

We would like to express our appreciation to the Southern Arkansas University Research Committee for providing funds to aid in this study.

T. W. STEWARD, J. D. WILHIDE, V. RICK McDANIEL, and DANIEL R. ENGLAND, Department of Biological Science, Arkansas State University, State University, AR 72467; Department of Biology, Southern Arkansas University, Magnolia, AR 71753.
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Each submitted paper should contain results of original research, embody sound methods 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.

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The author should submit two copies of the manuscript, tables, and figures. Manuscripts must be double spaced (preferably typed with a carbon ribboned typewriter) on 8½ x 11 inch bond paper with at least one inch margins on all sides. Do not 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 co-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.

A feature article comprises approximately six or more typewritten pages. A PROCEEDINGS printed page is equal to approximately three and one-half typewritten pages and the author is assessed a PAGE CHARGE (see Procedure section). A separate title page, including the title in capital letters, the authors names and addresses should be included with the manuscript. Feature articles are often divided into the following sections: abstract, introduction, materials and methods, results, discussion, acknowledgments, and literature cited. These sections should be centered and capitalized. Subheadings should begin at the left-hand margin, but more than one subheading should be avoided.

A general note is usually one to five typewritten pages and rarely utilizes subheadings. A note should have the title (capitalized) at the top of the first page with the body of the paper following. Abstracts are not used for general notes. The authors name and address should appear at the end of the manuscript.

Abbreviations: Use of abbreviations and symbols can be ascertained by inspection of recent issues of the PROCEEDINGS. Suggestions for uniformity include the use of numerals before units of measurements (5 millimeters), but nine animals (10 or numbers above, such as 13 animals). Abbreviations must be defined the first time they are used. The metric system of measurements and weights must be employed.

The literature cited section should include six or more references; entries should take the following form:


If fewer than six references are cited they should be inserted in text and take these forms: (Jones, The adrenal cortex, p. 210, 1957; (Davis, J. Anim. Ecol., 2:232-238, 1933).

Tables and illustrations: Tables and figures (line drawings, graphs, or black and white photographs) should not repeat data contained in the text. The author must provide numbers and short legends for illustrations and tables and place reference to each of them in the text. Legends for figures should be typed on a separate piece of paper at the end of the manuscript. Do not run tables in the text. Illustrations must be of sufficient size and clarity to permit reduction to standard page size and need not be larger than twice the size of intended reduction and whenever possible no larger than a manuscript page for ease of handling. Photographs must be printed on glossy paper: sharp focus and high contrast are essential for good reproduction. Figures and labeling must be of professional quality. Notifications identifying author, figure number, and top of print must be made on the back of each illustration. All illustrations must be submitted in duplicate. Tables should be typed with a carbon-ribboned typewriter and in the exact format that the author wishes them to appear in the text. Tables will be printed using the offset process and thus must be of professional quality when submitted. Note preferred placement of figures and tables in the margins of the manuscript.

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Evaluation of a paper submitted to the PROCEEDINGS begins with a critical reading by the Editor. The paper is then submitted to referees for checking of scientific content, originality, and clarity of presentation. Attention to the preceding paragraphs will greatly speed up this process. Judgments as to the acceptability of the paper and suggestions for strengthening it are sent to the author. If the paper is tentatively accepted the author will rework it, where necessary, and return two copies of the revised manuscript together with the original to the Editor. Usually a ten day limit for this revision will be requested. If the time limit is not met, the paper may be considered to be withdrawn by the author and rejected for publication. All final decisions concerning the acceptance or rejection of a manuscript are made by the Editor.

When a copy of the proof, original manuscript, and reprint order blanks reach the author, they should be carefully read for errors and omissions. The author should make corrections on the proof and return both the proof and manuscript to the Editor within 48 hours or the proof will be judged correct. Printing charges accruing from excessive additions to or changes in the proofs must be assumed by the author. Reprint orders are placed with the printer, not the Editor. Page charges are $25/printed page or portion thereof. These charges and excessive printing charges will be billed to the author by the Academy of Science.

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Abstracts of North American Geology
Biological Abstracts
Chemical Abstracts
Mathematical Reviews
Recent Literature of the Journal of Mammalogy
Science Citation Index
Sport Fishery Abstracts
Wildlife Review
Zoological Record
Review Journal of the Commonwealth Agricultural Bureau

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# TABLE OF CONTENTS

Secretary's Report and Financial Statement .............................................. 1
Program ........................................................................................................... 7

## FEATURE ARTICLES

GARY E. TUCKER: In Memoriam: Delzie Demaree 1889-1987 ....................... 16
ROBERT T. ALLEN: Additions to the known endemic flora and fauna of Arkansas 18
ROBERT T. ALLEN: A new species of Occaslapyx from the Interior Highlands ........................... (Insecta: Diplura: Japygidae) 22
RICHARD A. ATWILL and STANLEY E. TRAUT: Mandibular dentition in six species of salamanders, genus *Plethodon* (Caudata: Plethodontidae), from Arkansas using scanning electron microscopy......................... 24
R. H. DILDAY: Effect of nitrogen fertilizer on milling quality of rice (*Oryza sativa*) . 26
DANNY J. EBERT and STEPHEN P. FILIPEK: Response of fish communities to habitat alteration in a small Ozark stream ........................................... 28
JAMES M. GULDIN, TIMOTHY T. KU, and R. SCOTT BEASLEY: Forestry on the Island of Taiwan, ROC - the state of the art .................................................. 33
C. KAY HOLTMAN, TAMMY K. EBSEN, JUDITH A. BEAN, J. SCOTT BRYLES, and THOMAS J. LYNCH: Comparison of cyclic nucleotide phosphodiesterase in *Physarum flavicomum* ...................................................................... 37
R. A. KLUENDER, T. B. WIGLEY, and M. E. CARTWRIGHT: Factors affecting annual deer harvest in Arkansas .................................................. 45
M. A. MGONJA, R. H. DILDAY, S. L. SKINNER, and F. C. COLLINS: Association of mesocotyl and coleopetle elongation with seedling vigor in rice .............................. 52
THOMAS A. NELSON, LUKE EGERRING, and DANNY ADAMS: Autumn foods of white-tailed deer in Arkansas .................................................. 56
JAMES H. PECK and CAROL J. PECK: A bibliographic summary of Arkansas field botany .................................................................................................................. 58
JAMES H. PECK and CAROL J. PECK: Distribution, abundance, status, and phytogeography of Log Ferns (*Dryopteris*: Woodsiaiceae) in Arkansas ....................... 74
DAVID A. SAUGEY, GARY A. HEIDT, DARRELL R. HEATH, TIM W. STEWART, DANIEL R. ENGLAND, and V. R. MCDANIEL: Distribution and status of the Brazilian Free-tailed Bat (*Tadarida brasiliensis cuneocephala*) in Arkansas .................................................. 79
DAVID SAUGEY, DIANNE G. SAUGEY, GARY A. HEIDT, and DARRELL R. HEATH: The bats of Hot Springs National Park, Arkansas .................................................. 81
STANLEY E. TRAUT: Eggtooth development and morphology in the six-lined racerunner, *Cnemidophorus sexlineatus* (Sauria: Teiidae), using scanning electron microscopy .................................................................................................................. 84
STANLEY E. TRAUT and J. D. WILHIDE: Toe tip surface morphology in six species of salamanders, genus *Ambystoma* (Caudata: Ambystomatidae), from Arkansas using scanning electron microscopy .............................. 86
RENN TUMILSON and V. RICK MCDANIEL: Comments on estimating population rate of increase from age frequency data .................................................. 89
RENN TUMILSON and V. RICK MCDANIEL: Sex ratios in bobcat populations .......... 92
T. B. WIGLEY and M. E. GARNER: Forest habitat use by white-tailed deer in the Arkansas coastal plain .... 96
J. L. YEISER: Seedling response in a greenhouse to four rates of old and new paper mill sludge .................................................................................................................. 99
J. L. YEISER and J. W. BOYD: Survival and growth two years after control of herbaceous competitors in newly planted seedlings of loblolly pine .................................................. 102
J. L. YEISER, J. W. BOYD, and D. J. REED: Control of herbaceous competitors in progeny tests using container-grown seedlings .................................................. 105

## GENERAL NOTES

THOMAS J. AURELI and LES TORRANS: Spawning frequency and fecundity of Blue Tilapia ................................................................................................. 108
J. B. BENNETT: Equations of variation for ordinary differential equations on manifolds ................................. 109
PHOEBE A. HARP and HARVEY E. BARTON: Notes on the biology of *Thyanta calceata* (Hemiptera: Pentatomidae) on *Tephras virginiara* (Leguminosae), a new host plant .................................................. 110
WALTER E. MESHAKA: Reproductive characteristics of South Florida *Sternotherus odoratus* and *Kinosternon baurii* (Testudines: Kinosternidae) .................. 111
J. G. ROSS, S. R. ADDISON, N. O. GAISER: Measurements of the drag on spheres falling through the air .................................................................................................................. 112
WILLIAM SHEPHERD, JOSEPH NEAL, THOMAS FOTI, and DOUGLAS JAMES: Extralimital hummingbirds in Arkansas .................................................. 113
T. W. STEWART, J. D. WILHIDE, V. RICK MCDANIEL, and DANIEL R. ENGLAND: Mammalian species recovered from a study of Barn Owl, *Tyto alba*, pellets from southwestern Arkansas ................................. 115