Arkansas Academy of Science, Dept. of Physical Sciences, Arkansas Tech University

PAST PRESIDENTS OF THE ARKANSAS ACADEMY OF SCIENCE

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INSTITUTIONAL MEMBERS

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

ARKANSAS STATE UNIVERSITY, Jonesboro
ARKANSAS TECH UNIVERSITY, Russellville
JOHN BROWN UNIVERSITY, Siloam Springs
SOUTHERN ARKANSAS UNIVERSITY, Magnolia
UNIVERSITY OF ARKANSAS AT FAYETTEVILLE
UNIVERSITY OF ARKANSAS FOR MEDICAL SCIENCES, Little Rock
UNIVERSITY OF ARKANSAS AT MONTICELLO
UNIVERSITY OF ARKANSAS AT PINE BLUFF
UNIVERSITY OF THE OZARKS, Clarksville
UNIVERSITY OF ARKANSAS AT FORT SMITH

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B. Doria, U. Ozarks
S. Itza, U. Ozarks

COVER: From the crystal structure of the FGF –FGF receptor complex by J. Sakon and S. Kumar, UA Fayetteville.
ARKANSAS ACADEMY OF SCIENCE 2010

APRIL 9-10, 2010
94th ANNUAL MEETING

University of Arkansas at Little Rock
Arkansas
Secretary’s Report

MINUTES OF THE 94th MEETING

ARKANSAS ACADEMY OF SCIENCE
94th ANNUAL MEETING
SUMMARY OF BUSINESS MEETING
University of Arkansas at Little Rock
April 10, 2010

1. The meeting was called to order by President-elect Jeff Robertson substituting for President Scott Kirkconnell. The Academy membership and the LOC were met early Saturday morning with a campus-wide electrical outage thereby testing the resiliency and resolve of students, faculty and researchers alike. I am proud to say that we prevailed. Swapping the order of the business meeting for the scheduled talks to prolong our hope that city maintenance crews would restore power was valiant but in the end not enough. However, the individual session chairs and participants showed quite an astounding ability to improvise and adapt in holding their sessions after the business meeting anyway with a can-do attitude despite the lack of electron flow. Huddled around battery powered laptops and color PDF backup copies everyone gathered in their small groups for the exchange of scientific information and knowledge. It was quite epic and a testament to our dedication to the goals of the Academy and contributed to a memorable meeting!

2. Local Arrangements Committee, 2010: Marc Seigar Registration information, campus orientation, and meeting schedules were presented by Marc Seigar, LOC chair. There were 232 registered participants, 78 oral presentations and 72 posters with a ratio of 2:1 students to faculty and researchers making presentations.

3. Secretary’s Report: Jeff Robertson
Minutes from the 2009 November Executive Committee Meeting were reviewed and accepted. There were currently 100 AAS members (48 of which are life members). This number continues the decline in membership over the past 10 years. More discussion on that topic follows later.

4. Treasurer’s Report: Mostafa Hemmati
An accounting of the AAS “net worth” for 2009 was presented and discussed by the membership. The report was reviewed by an Academy auditing team and accepted by the membership.

5. Historian’s Report: Collis Geren
The AAS annual meeting this year at UALR will be the 94th meeting of the AAS and the fifth time at UALR, previous meetings were in 1976, 1981, 1987, and 2002.

The Academy thanks UALR chancellor Joel Anderson as well as the LOC members March Seigar, Al Adams, Brian Berry, Hassan Elsalloukh, Jamey Jones, and Olga Tarasenko.

The Academy introduces the new AAS Undergraduate Research Awards Program headed by Dr. Kurt Grafton of Lyon College (AAS Vice President).

The proceedings of the Academy are published in the Journal, which is now available online at http://libinfo.uark.edu/aas/ and through the AAS membership pages at http://www.ArkansasAcademyofScience.org.

6. Newsletter Editor’s Report: Jeff Robertson
The newsletter was sent out completely electronically and distributed to members past and
present, to all academic science departments of 4-year and 2-year institutions as well as related institutions throughout the state (e.g., Arkansas Game and Fish, US Forest Service, Natural Heritage Commission, etc).

7. **Journal (JAAS #64) Report: Editor-In-Chief Mostafa Hemmati & Managing Editor Ivan Still**

30 manuscripts were submitted at the spring meeting for publication in JAAS #63 and sent to 3 independent reviewers. Papers were returned with commentary before the end of July 2009. Authors received their feedback during July 15-28, 2009 and asked to submit their responses by August 31, 2009. This was also the deadline for page charges.

Three manuscripts were rejected because of unanimous rejection from the peer review process and three others were withdrawn.

Journal reviews, editing and payments were completed by the end of October of 2009. Journal authors now play an important role as the final editor for their publication. Their final submission is the “galley-proof” for the Journal and how the manuscript will appear in publication.

213 copies of JAAS 63 were purchased from Russellville printing for $3,144.08.

8. **Nominations Committee: Mostafa Hemmati**

Nominees were accepted for AAS Vice-president (Marc Seigar-UALR, Bill Doria-College of the Ozarks) and in a close vote, Marc Seigar was elected.

9. **Science Fair Association’s Report: Marc Bland (Christie Hicks)**

Support from the Academy of $400 for student awards requested.

10. **Arkansas Junior Academy of Science Report:**

Support from the Academy of $250 for student awards requested.

11. **Arkansas Science Talent Search (ASTS): Wil Slaton**

Student Siteng Ma from Little Rock Central High won 1st place in the talent search and the award presented at the Arkansas State Science Fair awards banquet. Support from the Academy of $100 for future student awards is requested.

Web site http://faculty.uca.edu/wvslaton/ASTS/

12. **Junior Humanities and Science Symposium (JSHS) Linda Kondrick**

Support from the Academy of $100 for student awards requested.

13. **Arkansas Science Teachers Association (ASTA):**

No Report

14. **Committee Reports:**

a. **Biota Committee: Doug James**

49 lists have been scanned and completed digitally on CD. 15 more animal and lower plant taxa lists are left to be completed including algae, mushrooms, liverworts, mosses, spiders and birds. Linking of the lists on the web from Univ. of Arkansas Fayetteville Biological Sciences to the Academy website is also planned.

b. **Development Committee: Betty Crump**

Two big tasks before us are 1) develop the search criteria for potential grant funding agencies, 2) hiring a grant writing specialist to assist in creating successful proposals, notwithstanding our membership decline issue. Travis Duckworth was introduced as a potential, eager and enthusiastic grant writing candidate for the Academy. Compensation structure for grant writing needs to be explored and finalized for work to begin.

Annual $1,000 institutional sponsorships from the Arkansas Natural Heritage Commission and the Ouachita National Forest are now in place. Need to have recognition in the JAAS. Other potential sponsors include but not limited to Arkansas Game and Fish Commission, US Geological Survey, Arkansas Nature Conservancy, etc.

A membership committee and perhaps a publicity committee need to be created. Perhaps improvements to the committee structure can be had by the Constitution and By-Laws revisions anticipated.

Remember to keep graduate awards on the radar as well as undergraduates.

15. **Business Old and New:**

a. The 95th annual AAS meeting will be April 8-9, 2011 at University of Arkansas at Monticello (UAM). The 96th annual meeting has been tentatively invited to Southern Arkansas University (SAU). Hosts for future meetings will be solicited, any takers?
b. The inaugural undergraduate research awards went to Nicole Segear (Hendrix College), Charlette Felton (Arkansas Tech University) and Jacob Teffs (University of Central Arkansas).

16. Action Items:
   a. Marc Seigar elected to Vice-president.
   b. AAS constitution and by-laws need review at fall 2010 Executive Committee Meeting.
   c. Non-JAAS budget approved:
      $2,500 Undergraduate Research Grants
      $2,750 Membership campaign (Kurt Grafton)
      $1,200 AAAS representative travel (Betty Crump)
      $850 Affiliate Awards (i.e. ASTS, JSHS, Jr. Academy, Science Fair)
      $1,000 AAS Spring meeting student awards
      $8,300 TOTAL (excludes costs associated with JAAS publication)
   d. Submit letter of recognition to $1,000 institutional sponsoring officials and recognition in JAAS publication.
   e. Need to solicit ideas from membership about activities the AAS should be pursuing in order to prioritize. Online survey to be developed and distributed to membership.
   f. Invited talks at meetings
   g. Pay for student travel and/or hotel room to AAS spring meeting
   h. Increased amounts for student awards
   i. Increased numbers of student awards
   j. Scholarships
   k. Web presence for spring meeting, earlier and including topics of talks
   l. Increase membership and participation from STEM “faculty” (i.e. NCTR, USGS, USDA, etc.) at non-academic institutions.
   m. Research award money for students/faculty
   n. College (student) chapters of the AAS
   o. Workshops at meetings
   p. Enhanced communication and promotion of AAS activities
   q. Special sessions at meetings
   r. Pursue institutional sponsorships
   s. Pursue external grant sources to fund AAS activities

17. Motions:
   a. Establish a membership committee.
   b. AAS budget (outside of Journal costs) passed for 2010-2011.
   c. Pending reports from these groups, approval of funding student awards is requested (Junior Science and Humanities Symposium $100, Arkansas Science Fair Association $400, Arkansas Junior Academy of Science $250, Arkansas Science Talent Search $100).

Meeting Adjourned – 9:40 am

Jeff Robertson, AAS Secretary

Treasurer’s Report
ARKANSAS ACADEMY OF SCIENCE
2010 FINANCIAL STATEMENT
December 16, 2010

Balance – December 16, 2010 $73,303.29
Balance – December 28, 2009 $66,296.30
Net Gain $7,006.99

DISTRIBUTION OF FUNDS
Checking Account $8,027.41
   Bank of the Ozarks, Russellville, AR, 12-16-2010
Certificate of Deposit $18,182.46
   Bank of the Ozarks, Russellville, AR, 12-16-2010
   Previous CD + $3,000 from the Bank of Ozark’s Checking, New Maturity Date 09-11-2011
Dwight Moore Endowment $20,415.46
   (Dwight Moore’s final balance of $6,002.73 + Short term CD’s final balance of $4,157.77 + $9,839.50 from the Bank of the Ozarks checking account = $20,000. The new CD will mature on 01-10-2011).
Phoebe and George Harp Endowment $18,572.41
   ($7601 Harp+ $6515.15CD+ $3383.85Checking)=
   $ 17500 CD + Interest Paid
Short Term CD $8,105.55
   Bank of the Ozarks, Russellville, AR, 10-25- 2010
   Maturity date 04-27-2011.
Combined interest on all accounts as of 12-16- 2010 was $1,049.83
Total $73,303.29
# Business meeting report

## INCOME:

1. **Transfer from CD to Checking**  
   - Amount: $1,338.40

2. **Gifts Received**
   - Ouachita National Forest - Sponsorship: $1,000
   - Arkansas Heritage Central AD - Sponsorship: $1,000
   - **Total Gifts Received**: $2,000

3. **Interest** (Interest Earned Year to Date, ~ December 16, 2010)
   - Checking Account, Bank of the Ozarks, …448: $3.66
   - CD1 (Bank of the Ozarks), …….594: $137.16
   - CD2 (Bank of the Ozarks), ….929: $219.80
   - CD3 (Bank of the Ozarks), ….583: $363.91
   - CD4 (Bank of the Ozarks),……396: $16.01
   - Checking Account, Bank of America -0-: -0-
   - CD4, (Bank of America - Closed), …..7627: $309.29
   - **All interest was added to the CDs**: $1,049.83

4. **Journal**
   - Page Charges: $6,250
   - Miscellaneous Sale: $200
   - Subscriptions: $1,550
   - **Total Journal**: $8,000

5. **Journal Contribution**
   - **Total Journal Contribution**: 0-

6. **Membership**
   - Associate: $15
   - Individual: $1,780
   - Institutional: $200
   - Life: $225
   - Sponsoring: $90
   - Individual from Annual Meeting (UALR): $2,385
   - Sustaining: $35
   - **Total Membership**: $4,730

7. **Miscellaneous Income**
   - Douglas James’ Extra Page Charges: $200
   - Journal Royalty: $107.67
   - Contribution from UALR – Annual Meeting: $1,082.79
   - **Total Miscellaneous Income**: $1,390.46

**Total Income**: $17,458.86

## EXPENSES:

1. **Student Awards**
   - Sarah Lewis: $100
   - Lahiana Mohamed Hassen: $50
   - Gail Bridges: $50
   - Andrea Long: $100
   - Maureen McClung: $50
   - Richard Walker: $50
   - Shane Sullivan: $100
   - Sharon Pilla: $50
   - Allan Thomas: $50
   - William Griffin: $100
   - Allison Chinn: $100
   - Derek Karr: $50
   - Melissa Kuehl: $50
   - Nitish Narula: $100
   - Joshua Brown: $100
   - Kendall Barnett + Tori Jones: $50
   - Roy Downs: $50
   - Charlotte Felton: $100
   - Dawn Johnson: $50
   - **Total Student Awards**: $1,350

2. **Awards (Organizations)**
   - Junior Science and Humanities Sym.: $100
   - Arkansas State Science Fair: $400
   - Arkansas Junior Academy of Science: $250
   - Arkansas Science Talent Search: $150
   - **Total Awards (Organizations)**: $900

3. **Undergraduate Research Awards**
   - Dr. Willyard, Hendrix College: $500
   - Dr. Burris, UCA: $400
   - Dr. Mebi, ATU: $500
   - **Total Undergraduate Research Awards**: $1,400

4. **Journal**
   - Volume 63 Printing Cost: $3,144.08
   - Journal Editorial Cost: 0
   - **Total Journal**: $3,144.08

5. **Newsletter**
   - **Total Newsletter**: 0-

6. **Miscellaneous Expenses**
   - Half of Dr. Kirkconnell’s Trip: $473.09
   - Journals Returned from Blackwell: $150
   - Dr. Kirkconnell’s Plaque: $48.40
   - Awards’ (Checks and Letters) Mailing Cost: $10.36
   - Returned Dr. James’ Manuscript Payment: $200
   - Cost of Checks Ordered: $16.95
   - Volume 63 Journal Mailing Cost: $113.45
   - Membership Campaign, Lyon College: $2,750
   - Fall EXCOM (Jeff, $19.53+Scott, $19.55): $39.08
   - **Total Miscellaneous Expenses**: $3,801.33

7. **Transfer to CD from Checking**
   - Transferred $300 to Cd # ………10929
   - **Total Transfer to CD from Checking**: $3,000.00

**Total Expenses**: $13,595.41

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Journal of the Arkansas Academy of Science, Vol. 64, 2010
## ARKANSAS ACADEMY OF SCIENCE
### COST OF JOURNAL

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The Total Volume Cost equals the printer’s charge plus the editor, editorial assistant, and other miscellaneous charges.

- On Volume 42 the Academy received 560 copies, but the printer did not charge us for the extra 110 copies. For comparison purposes the calculated cost/copy is based on 450 copies.
- On Volume 43 the Academy received 523 copies, but the printer did not charge us for the extra 73 copies. For comparison purposes the calculated cost/copy is based on 450 copies.
- On Volume 44 the Academy received 535 copies, but the printer did not charge us for the extra 85 copies. For comparison purposes the calculated cost/copy is based on 450 copies.
- On Volume 45 the Academy received 594 copies, but the printer did not charge us for the extra 144 copies. For comparison purposes the calculated cost/copy is based on 450 copies.
- On Volume 46 the cost was greater than usual due to the high cost of a second reprinting of 54 copies by a different printer.
APPENDIX A

2010 AAS Presentation Award Winners

GRADUATE STUDENT AWARDS

Poster Awards

1st Place: “Leaf Decomposition of a Non-Native Species in an Urban Stream” by Sarah E. Lewis and Art V. Brown of the University of Arkansas.

2nd Place: “Stimulatory and protective role of glycoconjugates on rice seeds from Bacillus spores infection during germination and growth” by Lahiana Mohamed Hassen and Olga Tarasenko of the University of Arkansas at Little Rock.

3rd Place: “Organics in Precipitation: Links to Carbonaceous Aerosols and Climate” by Gail L. Bridges, Jeffrey Gaffney and Nancy Marley of the University of Arkansas at Little Rock.

Oral Presentation Awards

Graduate Life Sciences

1st Place: “American Woodcock Migration Chronology and Clearcut use within Central Arkansas” by Andrea Long and Alexandra Felix-Locher of the University of Arkansas at Monticello.

2nd Place: “Fire affects food availability for birds: the response of leaf litter arthropods to woodland restoration in the Ozark mountains” by Maureen R. McClung and Kimberly G. Smith of the University of Arkansas.

3rd Place: “Movement patterns and environmental influences of two cyprinids in an intermittent reach of an Ozark stream” by Richard H. Walker, Ginny Adams and S. Reid Adams of the University of Central Arkansas.

Graduate Physical Sciences

1st Place: “Spectroscopic characterization and catalytic oxidation studies of a Fe complex of Tetraamidomacrocyclic Ligand” by Shane Z. Sullivan, Anindya Ghosh and Sharon Pulla of the University of Arkansas at Little Rock.

2nd Place: “Oxidation of alcohols to aldehydes using environmentally benign Iron(III) and copper-amide complexes” by Sharon Pulla, Anindya Ghosh and Shane Z. Sullivan of the University of Arkansas at Little Rock.

Graduate Environmental Sciences

1st Place: “Computational modeling of metal hydrides for use in hydrogen storage” by William O. Griffin and Jerome A. Darsey of the University of Arkansas at Little Rock.

UNDERGRADUATE STUDENT AWARDS

Poster Awards

1st Place: “Genetic analysis of regions on chromosome Z for contribution to pulmonary hypertension and Ascites in the chicken” by Allison M. Chinn, Nicholas B. Anothony, Gisela F. Erf, Robert F. Wideman and Doug D. Rhoads of the University of Arkansas.

2nd Place: “Bis(m – naphthalene – 2 - thiolato) diironhexacarbonyl complex: A catalyst for hydrogen production” by Derek Karr and Charles A. Mebi of the University of Arkansas.

3rd Place: “Photosynthetic microorganisms from Ozark region caves” by Melissa Kuehl, Michael V. McQueen, Martha Moreno, Han Chuan Ong and David J. Thomas of Lyon College.

Oral Presentation Awards

Undergraduate Life Sciences


Undergraduate Physical Sciences

1st Place: “Development of a double-isotope UPLC-MS/MS method for the determination of plasma citrulline concentration” by Joshua D. Brown of the University of Arkansas.
Be it resolved that we, the membership of the Arkansas Academy of Science, offer our thanks and appreciation to the University of Arkansas at Little Rock for hosting our 94th annual meeting. We especially thank the members of the Local Arrangements Committee for the time and effort they put in to the excellent organization of the meeting: Marc Seigar, chair, and Al Adams, both of the Department of Physics and Astronomy at UALR; Brian Berry from the Department of Chemistry; Hassan Elsalloukh from the Department of Mathematics and Statistics; Jamey Jones from the Department of Earth Science; and Olga Tarasenko from the Department of Biology. We also want to express our appreciation to Tiffany Baker, Laura Beck and Derek Bryce, the staff from the UALR Conference Services and Dining Services, and all the student workers who helped make the meeting possible: Amber Sierra, Liz Alvarez, Ismaeel Al-Baidhany, Jonathan Eller, and Casey Pavan. We thank Chancellor Joel Anderson for hosting the AAS and Provost and Vice Chancellor for Academic Affairs David Belcher for his gracious welcome.

The membership of the Academy are indebted to those who assumed the important role of session chairs: Brian Berry, Don Bragg, William Doria, Joyce Hardin, Mostafa Hemmati, Ronald Johnson, Forrest Payne, Jeff Robertson, David Saugey, Lynne Thompson, Patrick Treuthardt, and Brian Wagner. We are also grateful to all those who volunteered to serve as judges, without whom the awards and recognition of our student participants would not be possible.

We congratulate all who presented papers and posters at this meeting, and we thank all the undergraduates who applied to our first annual Undergraduate Research Funding program. We appreciate the involvement of so many students since their work and success directly contributes to the future success of the Academy and the improvement and advancement of science in the state of Arkansas.

The membership of the Academy also recognizes that the work done by and through our organization takes place throughout the year, and we therefore thank the directors of the various science and youth organizations which are supported or supervised by the Academy: Mark Bland, Science Fair Association; Nolan Carter, Junior Academy of Science; Will Slaton, Arkansas Science Talent Search; James Miller, Arkansas Science Teachers Association; and Linda Kondrick, Junior Science and Humanities Symposium. We also want to thank all those who helped organize and direct Regional Science Fairs and Junior Academy meetings. We also offer our sincere thanks to those who served in leadership positions within the Academy: Scott Kirkconnell (President), Jeff Robertson (President-Elect, Newsletter Editor, and Webmaster), Anthony Grafton (Vice-President), Mostafa Hemmati (Treasurer and Journal Editor-in-Chief), Ivan Still (Journal Managing Editor), Collis Geren (Historian), and Betty Crump (Development).

Respectfully submitted on this 10th day of April, 2010.

Resolutions Committee
Anthony K. Grafton, AAS Vice-President
Marc Seigar, UALR LOC Chair
## 2010-2011 MEMBERSHIP

### LIFE MEMBERS

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Journal of the Arkansas Academy of Science, Vol. 64, 2010
MAJOR INSTITUTIONAL SPONSORS

The Arkansas Academy of Science is an essential component in the science, technology, engineering and math pipeline for Arkansas. As a coalition of Arkansas scientists, it provides a local vehicle for presentation and publication of early scientific accomplishments in Arkansas. By promoting the work of Arkansas students, the Academy increases collaboration among the scientific community and provides a comprehensive network for scientific academics. These endeavors promote a higher standard of education within Arkansas and will encourage and promote a higher quality of life through educational opportunities.

As an integral part of the development and promotion of the Academy’s mission, we wish to recognize the commitment and continued support of our Institutional Sponsors, The Arkansas Natural Heritage Commission and the Ouachita National Forest.

ARKANSAS NATURAL HERITAGE COMMISSION

Since 1973, the Arkansas Natural Heritage Commission (ANHC) has been working to conserve Arkansas’s natural landscape. ANHC conducts research to determine which elements (species and natural communities) are most in need of protection. Field inventory documents the locations of elements of conservation concern. Information is also gathered from other sources, such as herbarium and museum collection records, and scientific publications such as the Journal of the Arkansas Academy of Science. ANHC’s current strategic planning goals include working to expand the ecological literacy of Arkansans. The Arkansas Academy of Science is a critical partner in helping to address this goal and, in the long term, protect the natural heritage of our state. For more information about the ANHC research, inventory and protection efforts, including the System of Natural Areas around the state, visit the agency website at www.naturalheritage.com. Here is a link to the current enewsletter featuring our support info as well. http://www.naturalheritage.com/enews/archive.aspx?mid=13361.

OUACHITA NATIONAL FOREST

Stretching from near the center of Arkansas to southeast Oklahoma, the pristine 1.8 million acre Ouachita National Forest is the South's oldest national forest, established on December 18, 1907 by President Theodore Roosevelt. Rich in history, the rugged Ouachita Mountains were first explored in 1541, by Hernando DeSoto's party of Spaniards. French explorers followed, flavoring the region with names like Fourche la Fave River. "Ouachita" is the French spelling of the Native American word "Washtita" which means "good hunting grounds." The Forest's ecosystem management policy guarantees its management regime as an ecological approach, based upon the most current knowledge and best science, for providing multiple benefits from the Forest and encouraging careful use of the forest for the future. The research local to Arkansas and the Forest published by the Journal of the Arkansas Academy of Science is critical to informing and supporting appropriate management decisions, environmental assessments and biological evaluations. The Ouachita National Forest extends support of the Academy’s efforts through this sponsorship.

For more information about the Forest, visit our webpage at: http://www.fs.fed.us/r8/ouachita.
A TRIBUTE TO Dr. DAVID A. SAUGEY

As a new assistant professor at Arkansas State University in August, 1984, I was eager to get to know as many field biologists with my interest (herpetology) in the state as possible. My departmental chair at that time, the late Dr. V. Rick McDaniel, suggested I contact a former graduate student of his, David A. Saugey, who happened to be a recently-hired U.S. Forest Service district biologist stationed out of the Jessieville office in the Ouachita National Forest. From our initial correspondence and informal meeting at my first Arkansas Academy of Science annual meeting in the spring of 1985, it became very clear to me that David was willing to assist me in my herpetological research efforts in Arkansas. Although a bat biologist by training, David also had a keen interest in amphibians and reptiles. For example, he was instrumental in protecting several abandoned mine shafts in the Ouachita Mountains by having their entrances gated and, in doing so, helped conserve these unique habitats for brooding plethodontid salamanders as well as several bat species that utilized those mines.

David became a member of the Arkansas Academy of Science one year ahead of me in 1986. By then, we had begun a professional partnership and friendship that continues to exist today. Since 1990, he and I have co-authored papers and presentations on various aspects of salamander biology.

David has devoted much time and energy toward making the Academy a top-notch state society. Not only has he performed the duties of Newsletter Editor (1995-1998), Managing Editor of the Journal (1999-2002), and President of the Academy (2007), but he has also served on many ad-hoc committees and was the host of the Local Committee for the 2000 annual meeting of the Academy held in Hot Springs. For all of these outstanding contributions to the mission and success of the Academy, we gratefully recognize David this year and wish him the best as he enters retirement.

Stan Trauth, Professor
Department of Biological Sciences
Arkansas State University

Figure Legend. Left: David holding a bear cub; Right: David at the gated entrance to Spillway Mine in Garland County, Arkansas.
Major earthquakes have occurred in the central US (CUS), the most famous being the 1811-1812 New Madrid sequence of magnitude 7-8 earthquakes. Magnitude greater than 6 New Madrid earthquakes also occurred in 1843 and 1895. These earthquakes were felt over a wide area of the eastern US. More recently in 2008 a magnitude 5.2 earthquake struck near Mt. Carmel, Illinois in the Wabash Valley seismic zone. The geologic records of earthquake-induced liquefaction indicate large damaging earthquakes have occurred in the recent geologic past in both of these seismic zones. So the potential for damaging earthquakes is significant in the CUS. National, regional, and local seismic hazard maps help us understand what the earthquake hazard is in a region. My presentation will introduce you to the basics of earthquake hazard, including the two kinds of seismic hazard maps, scenario and probabilistic. Seismic hazard depends on the expected magnitude and in some cases the rate of earthquakes in the surrounding region. I will review the geologic and geodetic evidence for large earthquakes in the New Madrid seismic zone and surrounding region. While there appears to be contradictions between geologic and geodetic observations, these contradictions are less in conflict than they seem. However, the reason for earthquakes occurring in the CUS is still poorly understood and lots of mechanisms for their occurrence have been suggested. Nonetheless, the geologic record suggests that earthquake hazard is fairly high. So preparing for the future occurrence of damaging earthquakes is important. A major effort to better understand why earthquakes occur in the CUS is associated with the Earthscope transportable array of seismographs that starts passing through the CUS in 2010.

Dr. Cramer worked for 23 years for the California Division of Mines and Geology (now California Geological Survey) and 7 years for the U.S. Geological Survey prior to coming to work for CERI at the University of Memphis. During that period he worked in several areas of seismology including probabilistic earthquake hazard and risk, strong ground motion and the effects of site geology, earthquakes and volcanoes, and field seismological studies of geothermal areas, aftershock sequences, reservoir induced seismicity, and the earthquake activity potential of faults. He also has extensive experience with programming and using computer systems to process, model, and interpret geophysical data. As an undergraduate and during his first two years as a graduate student, Chris worked on geophysical problems and did field work in the areas of gravity, magnetism, and geodesy.
SECTION PROGRAMS

ORAL PRESENTATIONS

SESSION 1: FRIDAY 1:00-2:30.
CHAIR: RONALD JOHNSON
LEDBETTER A, DONAGHEY STUDENT CENTER
Topics: Zoology, Ecology

1:00
NEW RECORDS OF THE BADGER (TAXIDEA TAXUS) IN ARKANSAS, WITH EMPHASIS ON RANGE EXPANSION INTO NORTHEASTERN ARKANSAS
Tumlinson, Renn; Sasse, D. Blake; Cartwright, Michael E.; Brandenbura, Stephen C.; Klotz, Tracy. Henderson State University, Arkansas Game and Fish Commission. Arkansas State University

1:15
NEW RECORDS AND NOTES ON THE NATURAL HISTORY OF SELECTED VERTEBRATES FROM SOUTHERN ARKANSAS
Tumlison, Renn; Robison, Henry. Henderson State University. Southern Arkansas University

1:30
DISTRIBUTION OF THE SOUTHEASTERN SHREW (SOREX LONGIROSTRIS) IN ARKANSAS
Mikel, Garrett A.; Clark, David W. University of Arkansas at Little Rock

1:45
FUTURE CLIMATE CHANGE SPELLS CATASTROPHE FOR BLANCHARD'S CRICKET FROG (ACRIS BLANCHARDI)
McCallum, Malcolm. Herpetological Conservation and Biology

SESSION 1: FRIDAY 1:00-2:30. CHAIR: BRIAN WAGNER
LEDBETTER C, DONAGHEY STUDENT CENTER
Topics: Marine Biology

1:00
STATUS AND DISTRIBUTION OF THE GAPPED RINGED CRAYFISH, ORCONECTES NEGLICTUS CHAENODACTYLYUS, IN ARKANSAS
Wagner, Brian K.; Taylor, Christopher A.; Kottmyer, Mark D. Arkansas Game and Fish Commission

1:15
NOTEWORTHY DISTRIBUTION RECORDS FOR THE ENDEMIC REDSPOTTED STREAM CRAYFISH, ORCONECTES ACARES (DECAPODA: CAMBARIDAE) IN ARKANSAS
McAllister, Chris T.; Robison, Henry W. RapidWrite. Southern Arkansas University

1:30
DISTRIBUTION AND LIFE HISTORY ASPECTS OF THE FRESHWATER SHRIMPS, MACROBRANCHIUM AND PALAEMONETES (DECAPODA: PALAEMONIDAE), IN ARKANSAS
Robison, Henry W.; McAllister, Chris T.; Harp, George L. Southern Arkansas University. RapidWrite. Arkansas State University

1:45
STRUCTURE AND FUNCTION OF LARGE WOOD IN OZARK HEADWATER STREAMS AND ITS EFFECT ON FISH COMMUNITY STRUCTURE
Mitchell, David; Entrekkin Sally; Adams, Ginny; Adams, Reid. University of Central Arkansas

SESSION 1: FRIDAY 1:00-2:30. CHAIR: MOSTAFA HEMMATHI
ROOM D, DONAGHEY STUDENT CENTER
Topics: Physics

1:00
SHOCK CONDITIONS AND ELECTRON DRIFT VELOCITY RANGE
Kilbourn, Amanda; Hemmati, Mostafa; Massey, Michael; Bramlett, Rebecca; Childs, William. Arkansas Tech University

1:15
SYNTHESIS AND DIELECTRIC MEASUREMENT OF POTASSIUM SODIUM TARTRATE (KNaC\(_4\)H\(_4\)O\(_6\)·4H\(_2\)O)
Kendall, Barnett A.; Jones, Tori R.; Crowell, Vernon D.; Hutton, Stuart L. Lyon College

1:45
P-TYPE ZnO NANOWIRES DOPED WITH Ag BY A LOW TEMPERATURE ELECTROCHEMICAL PROCESS
Thomas, M. Allan; Cui, Jingbiao. University of Arkansas at Little Rock. National Sun Yat-Sen University, Taiwan

SESSION 1: FRIDAY 1:00-2:30. CHAIR: MOSTAFA HEMMATHI
ROOM D, DONAGHEY STUDENT CENTER
Topics: Physics

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SESSION 1: FRIDAY 1:00-2:45. CHAIR: BRIAN BERRY  
ROOM G, DONAGHEY STUDENT CENTER  
Topics: Chemistry

1:00  
AEROSOL AND OZONE IMPACTS ON CLIMATE: AGRICULTURAL AND BILOGENIC FEEDBACKS  
Gaffney, Jeffrey S.; Marley, Nancy A. University of Arkansas at Little Rock

1:15  
The University of Arkansas at Little Rock (UALR) Atmospheric Observatory  
Marley, Nancy A.; Gaffney, Jeffrey S. University of Arkansas at Little Rock

1:30  
COMPUTATIONAL MODELING OF METAL HYDRIDES FOR USE IN HYDROGEN STORAGE  
Griffin, William O.; Darsey, Jerome A. University of Arkansas at Little Rock

1:45  
SPECTROSCOPIC CHARACTERIZATION AND CATALYTIC OXIDATION STUDIES OF A Fe COMPLEX OF TETRAAMIDOMACROCYCLIC LIGAND  
Sullivan, Shane Z.; Ghosh, Anindya; Pulla, Sharon; Pierce, Bradley S.; Schnackenberg, Laura. University of Arkansas at Little Rock. University of Texas, Arlington National Center for Toxicological Research

2:00  
OXIDATION OF ALCOHOLS TO ALDEHYDES USING ENVIRONMENTALLY BENIGN IRON(III) AND COPPER-AMIDE COMPLEXES  
Pulla, Sharon; Ghosh, Anindya; Sullivan, Shane Z. University of Arkansas at Little Rock

2:15  
MOLECULAR MODELING STUDIES OF GELDANAMYCIN AND ITS DERIVATIVES TO TREAT PARKINSON'S DISEASE  
Thotakura, Sushma; Darsey, Jerry. University of Arkansas at Little Rock

2:30  
PLATINUM NANOROD ARRAYS WITH ENHANCED ELECTROCATALYTIC ACTIVITY FOR OXYGEN REDUCTION REACTION  
Khadhayer, Wisam J.; Shaikh, Ali U.; Karabacak, Tansel. University of Arkansas at Little Rock

SESSION 2: FRIDAY 3:00-4:30. CHAIR: LYNNE THOMPSON  
LEDBETTER C, DONAGHEY STUDENT CENTER  
Topics: Insects, Arthropods

3:00  
PRESENCE OF THE ASIAN TIGER MOSQUITO (Aedes albopictus) IN NORTHWEST ARKANSAS  
Wilson, Jill; Jamieson, David H. NorthWest Arkansas Community College

3:15  
ARKANSAS BUG UPDATE 2010; INCLUDING 1 EXTREMELY RARE BUG  
Chordas III, Stephen; Tumlison, Renn; Robison, Henry; Connior, Matthew. The Ohio State University. Henderson State University. Southern Arkansas University. Southern Arkansas Community College

3:30  
ENDOCRINE DISRUPTION OF SEXUAL SELECTION IN THE MEALWORM BEETLE (Tenebrio molitor)  
McCallum, Malcolm L.; Treas, Justin; Marlock, Mackenzie; Safi, Barroq; Sanson, Wendy; McCallum, Jamie L. Herpetological Conservation and Biology. Texas Tech University. Texas Tech University-Texarkana. Texas State University. Louisiana State University-Shreveport. McCallumsflock.com

3:45  
RARE COMANCHE HARVESTER ANTS IN ARKANSAS—WHAT DO WE KNOW?  
Thompson, Lynne C.; General, David M. University of Arkansas at Monticello

4:00  
FURTHER SAMPLING IN ARKANSAS OF INSECTS INHABITING THE BURROWS OF BAIRD'S POCKET Gopher  
Kovarik, Peter W.; Connior, Matthew B.; Chordas III, Stephen W.; Skelley, Paul E.; Robison, Henry W. Columbus State Community College. Southern Arkansas University. The Ohio State University. Florida State Collection of Arthropods

4:15  
NEW RECORDS AND NOTES ON THE NATURAL HISTORY OF SELECTED INVERTEBRATES FROM SOUTHERN ARKANSAS  
Tumlison, Renn; Robison, Henry. Henderson State University. Southern Arkansas University

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SESSION 2: FRIDAY 3:00-4:45. CHAIR: WILLIAM DORIA
ROOM G, DONAGHEY STUDENT CENTER
Topics: Molecular Biology, Biophysics, Genetics

8:30
SEARCH FOR A "SILVER BULLET."
Black, Viktoria; Njewel, Guy. Southern Arkansas University

8:45
THE EFFECTIVITY OF THE WEIGHT CONTROL THROUGHT THE WEIGHT WATCH PROGRAMS
Black, Viktoria; Boumtje, Pierre. Southern Arkansas University

9:00
SEQUENCE DIFFERENCES AMONG CYP3A MEMBERS SIGNIFICANTLY IMPACT THE METABOLISM OF R- AND S-WARFARIN
Jones, Drew R.; So-Young, Kim; Yun, Chul-Ho; Boysen, Gunnar; Miller, Grover P. University of Arkansas for Medical Sciences. Chonnam National University

9:15
CYP2C19 METABOLIZES BOTH R- AND S-WARFARIN TO ENANTIOMERS OF FOUR HYDROXYWARFARINS
Kim, So-Young; Jones, Drew R.; Yun, Chul-Ho; Boysen, Gunnar; Miller, Grover P. University of Arkansas for Medical Sciences. Chonnam National University

9:30
ANTIGENICITY DETERMINATION AND CHARACTERIZATION OF AN ANTI-PEPTIDE POLYCYCLICAL ANTIBODY AGAINST HUMAN MULTIPLE INOSITOL PHOSPHOHATASE (MIPP) TO STUDY ITS PHYSIOLOGICAL FUNCTION
Hossain, Md. Zakir; Kleve, Maurice G. University of Arkansas at Little Rock

9:45
BINDING AND RECOGNITION OF BACILLUS CEREUS BY DICTYOSTELIUM DISCOIDEUM USING GLYCOCONJUGATES
Rasol, Aveen; Tevebaugh, Whitney; Bush, John; Tarasenko, Olga. University of Arkansas at Little Rock

SESSION 2: FRIDAY 3:00-4:30. CHAIR: JEFF ROBERTSON
ROOM D, DONAGHEY STUDENT CENTER
Topics: Physics, Engineering

3:00
BIOSENSOR APPLICATIONS IN BIOLOGICAL SCIENCES AND ENGINEERING AND DESIGN OF A NOVEL ELECTROCHEMICAL BIOSENSOR FOR BIODIESEL QUALITY SENSING
Hossain, Md. Zakir; Shrestha, Dev; Kleve, Maurice G. University of Arkansas at Little Rock. University of Idaho

3:15
TEMPERATURE CONTROLLED NANO-INDENTATION OF GRAPHEN SHEET
Downs, Roy; Terdalkar, Sachin S.; Rencis, Joseph J. University of Arkansas

3:30
HYDROPHOBIC METALLIC NANORODS WITH TEFLOMNANOPATCHES
Khudhayer, Wisam J.; Sharma, Rajesh; Karabacak, Tansel. University of Arkansas at Little Rock

3:45
Strain-Mediated Migration of Vacancy Defects in Graphene
Terdalkar, Sachin S.; Zhang, Sulin L.; Rencis, Joseph J. University of Arkansas. Pennsylvania State University

4:00
FORMATION OF NANO-INDIUM (III) SULFIDE/CADMIUM TELLURIDE STRUCTURES BY COMBINED EVAPORATION AND ELECTRODEPOSITION PROCESSES
Vangilder, Joshua A.; Engelken, Robert D.; Felizco, Frederick; Hall, John; Chaudhury, Z.; Thapa, S.; Karabacak, T.; Cansizoglu, F.; Seo, Hye-Won. Arkansas State University. University of Arkansas at Little Rock

4:15
SYNTHESIS OF BISMUTH (III) SULFIDE NANO/MICRO POWDERS FROM LOW COST/LOW HAZARD THIOSULFATE BATHS, AND VACUUM EVAPORATION AND SPRAY DEPOSITION OF SUCH
Felizco, Frederick M.; Engelken, Robert D.; Vangilder, Joshua A.; Hall, John; Thapa, Shyam; Chaudhury, Zariff. Arkansas State University
Meeting Report

10:00
LINKAGES BETWEEN PARENTAL NUTRITION AND HEALTH KNOWLEDGE, AND CHILDHOOD OBESITY
Boumtje, Pierre I.; Huang, Chung L.; Lee, Jonq-Ying; Lin, Biing-Hwan.
Southern Arkansas University. University of Georgia. University of Florida. US Department of Agriculture

10:15
KNOWLEDGE COMPLEX PROTEINS AFFECTS GLYCOSYLATION AND RETROGRADE TETHERING
Smith, Richard D.; Morelle, Wille; Lupashin, Vladimir.
University of Arkansas for Medical Sciences. University of Lille, France

SESSION 3: SATURDAY 8:30-10:30. CHAIR: FORREST PAYNE LEDBETTER C, DONAGHEY STUDENT CENTER
Topics: Insects, Arthropods, Biology

8:30
A SURVEY FOR ENTAMOEBA FROM INVERTEBRATE HOSTS: INCREASING MOLECULAR DATA FOR THE ASSESSMENT OF EVOLUTIONARY HISTORY
Chang, Helen; Silberman, Jeffery D.
University of Arkansas

8:45
STRATEGIES TO DOCUMENT DIVERSITY OF WATER MITES (ACARI: HYDRACHNIDIAE) FROM THE INTERIOR HIGHLANDS AND FACILITATE THEIR INCLUSION IN FRESHWATER CONSERVATION EFFORTS AND ECOLOGICAL RESEARCH
Radwell, Andrea J.
University of Arkansas

9:00
FIRE AFFECTS FOOD AVAILABILITY FOR BIRDS: THE RESPONSE OF LEAF LITTER ARTHROPODS TO WOODLAND RESTORATION IN THE OZARK MOUNTAINS
McClung, Maureen R.; Smith, Kimberly G.
University of Arkansas

9:15
ACUTE EFFECTS OF ATRAZINE AND NITRATE ON HYALELLA AZTECA (AMPHIPODA) IN LABORATORY EXPOSURES
Pandey, Ram B.; Warren, Laurie; Adams, Ginny.
University of Central Arkansas

9:30
ACQUISITION OF IMMUNITY TO THE PROTOZOAN PARASITE EIMERIA ADENOEOIDES IN TURKEY POULTS AND THE PERIPHERAL BLOOD LEUKOCYTE RESPONSE TO A PRIMARY INFECTION
Gadde, Ujvala Deepthi; Chapman, Hilary D.; Rathinam, Thilkar; Erf, Gisela F.
University of Arkansas

9:45
Bacterial Responses to Diurnal Processes in Lake Maumelle
Stites, Courtney E.; Robinson, Amelia C.; Payne, Forrest E.; Johnson, Dawn; Sweeney, Sharon; Shry, Sam.
University of Arkansas at Little Rock

10:00
STAND CONDITIONS IMMEDIATELY FOLLOWING A RESTORATION HARVEST IN AN OLD-GROWTH PINE-HARDWOOD REMNANT
Bragg, Don C.
USDA Forest Service

10:15
THE CRABS CLAW (CRC) GENE TREE: A PHYLOGENETIC ANALYSIS OF THE EUDICOTS
Narula, Nitish; Krosnick, Shawn.
Southern Arkansas University

10:30
ACQUISITION OF IMMUNITY TO THE PROTOZOAN PARASITE EIMERIA ADENOEOIDES IN TURKEY POULTS AND THE PERIPHERAL BLOOD LEUKOCYTE RESPONSE TO A PRIMARY INFECTION
Gadde, Ujvala Deepthi; Chapman, Hilary D.; Rathinam, Thilkar; Erf, Gisela F.
University of Arkansas

10:45
THE DESIGN OF A NOVEL METHOD TO MEASURE PAIN WITHDRAWAL THRESHOLD IN PHYSIOLOGICAL STUDIES
Walker, Azida; Thurman, Skipper; Roisen, Alan; Dobretsov, Maxim.
University of Central Arkansas. University of Arkansas for Medical Sciences

SESSION 3: SATURDAY 8:30-10:30. CHAIR: DON BRAGG ROOM G, DONAGHEY STUDENT CENTER
Topics: Botany, Ecology

8:30
STAND CONDITIONS IMMEDIATELY FOLLOWING A RESTORATION HARVEST IN AN OLD-GROWTH PINE-HARDWOOD REMNANT
Bragg, Don C.
USDA Forest Service

8:45
YUCCA (AGAVACEAE) IN ARKANSAS
Johnson, George P.
Arkansas Tech University

9:00
CARBON MARKET IMPACTS ON ARKANSAS’S PINE FORESTS
Pelkki, Matthew H.
University of Arkansas at Monticello

9:15
THE CRABS CLAW (CRC) GENE TREE: A PHYLOGENETIC ANALYSIS OF THE EUDICOTS
Narula, Nitish; Krosnick, Shawn.
Southern Arkansas University

9:30
WHAT IS A NECTARY?
Krosnick, Shawn E.
Southern Arkansas University

9:45
SECOND YEAR OF A MULTI-YEAR STUDY OF THE EFFECTS OF VARYING CROP PRODUCTION TREATMENTS ON WATER AND SEDIMENT QUALITY
Little, J. R.; Sappington, D. E.; Brueggen, T. R.; Bouldin, J. L.
College of the Ozarks. Arkansas State University

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https://scholarworks.uark.edu/jaas/vol64/iss1/1
10:00
EVOLUTIONARY HISTORY OF SEXUAL AND APOMICTIC
ERIGERON TENUIS (ASTERACEAE)
Groff, Dulcinea; Noyes, Richard D. University of Central Arkansas

10:15
ARABIDOPSIS DEVELOPMENT IN LOW ATMOSPHERIC
PRESSURE
Taylor, James G.; Leonard, Mark. Ouachita Baptist University

POSTER PRESENTATIONS

BIOLOGY POSTERS

1. EXTENDING THE VASE LIFE OF CUT ROSES (ROSA
HYBRIDA) BY TREATMENT WITH DIFFERENT
PRESERVATIVES
Anderson, L. Jr; Islam, Shahidul. University of Arkansas at Pine Bluff

2. ECOLOGICAL DYNAMICS OF TWO COMMUNITIES OF
LIGNICOLOUS MYXOMYCETES IN COSTA
Rojas, Carlos; Stephenson, Steven L. University of Arkansas

3. LEAF DECOMPOSITION OF A NON-NATIVE-SPECIES IN
AN URBAN STREAM
Lewis, Sarah E.; Brown, Art V. University of Arkansas

4. MATE CHOICE IN MANTIDS: DOES SEXUAL
CANNIBALISM ALLOW FEMALES TO AVOID
INBREEDING
Hurley, Kyle; Davis, Nicholas. University of Central Arkansas

5. GENETIC DIVERSITY OF BUMBLE BEES IN ARKANSAS
Magnus, Roxane; Szalanski, Allen. University of Arkansas

6. A SURVEY OF ANTS IN SELECTED PRAIRIES IN
ARKANSAS
Thompson, Lynne C.; General, David M. University of Arkansas at Monticello

7. DETECTION OF INOSITOL POLYPHOSPHATES BY
POLYACRYLAMIDE GEL ELECTrophoresis (PAGE)
Zafar, Maroof; Rizan, Mohsin; Hassen, Samar; Agarwal, Rakhee; Ali, Nawab. University of Arkansas at Little Rock. University of Arkansas for Medical Sciences

8. MYXOMYCETES ASSOCIATED WITH BRYOPHYTES
Bates, Amanda; Doss, Robin; Rojas, Carlos; Stephenson, Steven. University of Arkansas

9. CHANGES IN INVERTEBRATE COMMUNITY STRUCTURE
ALONG A LONGITUDINAL GRADIENT IN BIG PINEY
CREEK, ARKANSAS
Fuller, Chris; Entrekin, Sally; Johnson, Clint; Adams, Ginny; Adams, Reid. University of Central Arkansas

10. THE EFFECTS OF NATURAL GAS DRILLING ON
DECOMPOSITION RATES IN THE FAYETTEVILLE SHALE
GAS PLAY
Troutman, Tyler; Lowry, Michael S.; Entrekin, Sally A. University of Central Arkansas

11. AN ECOLOGICAL STUDY OF WOOD-DECOMPOSING
FUNGI IN NORTHWEST ARKANSAS
Doss, Robin; Rojas, Carlos; Stephenson, Steven L. University of Arkansas

12. AN ECOLOGICAL SURVEY OF ARUNDAINARIA GIGANTEA
IN COLUMBIA COUNTY, ARKANSAS
Dockter, Katherine S.; Krosnick. Shawn E. Southern Arkansas University

13. THE EFFECT OF HYDROPERIOD AND INVERTEBRATE
FEEDING ON LEAF DECOMPOSITION RATES IN
INTERMITTENT OZARK STREAMS
Nix, Kasey J.; Entrekin, Sally A. University of Central Arkansas

14. A REVIEW OF CONSERVATION RESEARCH PRACTICES
IN MARINE AQUARIA
Canady, Candice S. Southern Arkansas University

15. THE PLANT DENSITY OF JUSTICIA AMERICANA IN LAKE
MAUMELLE, AN IMPOUNDMENT OF THE BIG
MAUMELLE RIVER, PULASKI COUNTY, ARKANSAS
Sweeney, Sharon M.; Meredith, Bradley G.; Peck, James H. University of Arkansas at Little Rock

16. PRELIMINARY DATA FROM INVERTEBRATE AND FISH
SURVEYS OF BIG MAUMELLE RIVER, ARKANSAS
Meredith, Bradley J.; Reese, Jeremy P.; Stehle, Jeremy P.; Mikel, Garrett A; Stroman, Justin A.; Payne, Forrest E. University of Arkansas at Little Rock

17. IDENTIFICATION OF POLYPHENOLS IN TOMATO
LEAVES BY HPLC WITH PHOTODIODE ARRAY
DETECTION AND ELECTROSPIRAY IONIZATION MASS
SPECTROMETRY
Grace, Stephen C. University of Arkansas at Little Rock

18. PHOTOREGULATION OF POLYPHENOL BIOSYNTHESIS
IN THE HP-2DG MUTANT OF TOMATO
Chen, Chen; Grace Stephen C. University of Arkansas at Little Rock

19. CALLING PHENOLOGY OF ANURAN POPULATIONS
SURVEYED IN SOUTHWEST ARKANSAS USING ACOUSTIC
SURVEYS
Risher, Sarah R.; Baker, Claude D. Southern Arkansas University

20. A KINEMATIC ANALYSIS OF DROP LANDING IN
MILITARY BOOTS
Booker, Jacquelynn M.; Oliver, Gretchen D.; Stone, Audrey J.; Plummer, Hillary. University of Arkansas

21. STUDENT PERCEPTIONS OF THE BMI AS AN OVERALL
INDICATOR OF HEALTH
Davis, Cory; Krosnick, Shawn E. Southern Arkansas University

22. A BIOLOGICAL INVENTORY OF MEACHAM CAVE
(INDEPENDENCE COUNTY, AR)
Thomas, David J.; Ong, Han C.; Foll, Megan N.; Robinson, Greg; Middaugh, Chris R.; Morgan, Charles. Lyon College

23. PHOTOSYNTHETIC MICROORGANISMS FROM OZARK
REGION CAVES
Kuehl, Melissa; McQueen, V. Michael; Moreno Martha; Ong, Han Chuan; Thomas, David J. Lyon College

24. THE TRANSFORMATION OF RUBUS AND ITS
APPLICATION TO THE STUDY OF PLANT SECONDARY
Gates, Nadine; Parker, Kayla; Walker, Courtney; Skiver, Natasha. University of Central Arkansas

25. STIMULATORY AND PROTECTIVE ROLE OF
GLYCOCONJUGATES ON RICE SEEDS FROM BACILLUS
SPORES INFECTION DURING GERMINATION AND
GROWTH
Hassen, Lahiani Mohamed; Tarasenko, Olga. University of Arkansas at Little Rock

26. AFLP MARKERS FOR MAPPING GENOMES IN PLANTS
Martin Jr., Darrell; Wild, Michael; Noyes, Richard D. University of Central Arkansas
27. SEGREGATION FOR SEED FORMATION IN COMPLEX APOMICT SEXUAL CROSSES IN PLANTS
   Burrow, Halee; Desrochers, Claire; Richardson, Harry; Brummett, Shawn; Noyes, Richard D. University of Central Arkansas

28. AFLP MARKERS FOR MAPPING GENOMES IN PLANTS
   Robers, Aaron; DiGiacomo, Rebecca; Noyes, Richard D. University of Central Arkansas

29. POLLEN SIZE VARIATION AND REPRODUCTIVE SUCCESS FOR TRIPLOID APOMICTIC PLANTS
   Larson, Signe; Noyes, Richard D. University of Central Arkansas

30. EFFECTIVENESS OF A GENTLE ON SPORE CONTAMINATED STAINLESS STEEL
   Pavan, Casey; Tarasenko, Olga. University of Arkansas at Little Rock

31. GENETIC ANALYSIS OF REGIONS ON CHROMOSOME Z FOR CONTRIBUTION TO PULMONARY HYPERTENSION AND ASCITES IN THE CHICKEN
   Chinn, Allison M.; Anthony, Nicholas B.; Erf, Gisela F.; Wideman, Robert F.; Rhoads, Doug D. University of Arkansas

32. MOLECULAR CHARACTERIZATION OF A FAMILY OF TRANSCRIPTIONAL REGULATORS – CCAAT-BINDING FACTORS – IN THE PLANT-PATHOGENIC FUNGUS Fusarium verticillioides THROUGH TARGETED GENE DISRUPTION
   Ridenour, John B.; Bluhm, Burt H. University of Arkansas

33. THE DISTRIBUTION OF ERM A AND ERM C AMONG STAPHYLOCOCCI
   Fu, Xing; Gilmore, David. Arkansas State University

34. BENTHIC MACROINVERTEBRATE FOOD WEB PATTERNS IN A HEADWATER STREAMS PRIOR TO RIPARIAN ZONE RESTORATION
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In Memoriam: Daniel Lee Marsh, 1933-2010

Dr. Dan Marsh, who spent his academic career working as a botanist in the Department of Biology at Henderson State University (HSU), was active in attending the annual meetings of the Arkansas Academy of Science, and was a Sustaining Member of the Academy. He regularly brought his students to those meetings to present results of their undergraduate research. Especially in the last decade preceding his retirement, Dan took several of his students to Academy meetings, where they presented their research and published in the journal.

Marsh was born 2 June 1933 in Jonesboro, AR. He entered higher education at Arkansas State College (ASC, now University, ASU), but as a freshman he was not sure whether to major in Biology or English. One of his professors, Delzie DeMaree (a botanist), suggested that he walk the perimeter of Arkansas to figure it out. In 1954, he made the 1,200 mile trek in 94 days, and newspaper articles even chronicled the journey. Studying nature along the way, he returned to school and began his development as a botanist.

Earning his B.S. degree at ASC in 1956, Dan next attended the University of Kansas, where he completed a study of Phlox as part of his M.A. program in 1958. He taught at Yellville High School for a few years, and during that time Dan was active in other enterprises including involvement with the Boy Scouts and service as a Red Cross swimming instructor and lifesaver. He also enjoyed cave exploration, and was part of several rescue missions for trapped spelunkers.

Dan began his doctoral work in 1965 at the University of Arkansas (UA). He completed his Ph.D. in 1977, having focused his research on cane (Arundinaria gigantea). Cane tends to grow clonally, and may go many years without blooming, so it is rare, even for botanists, to see the bloom of the plant. Among his colleagues, it is well-known that Dan was able to find cane in flower many times and at many locations across the state.

In 1968, well before the completion of his Ph.D., Dan had begun teaching at HSU. Developing a research collection of plant specimens, he curated his growing HSU Herbarium well, and eventually it achieved acclaim as one of the most active herbaria in the state.

During his professional career, Dan became very interested in bryophytes. Because they have no vascular tissue and lie close to the ground, he called his endeavors "belly botany". Bryophytes often do well in cemeteries, so Dan often could be found, with students and colleagues, prostrate on the ground in a cemetery. Police patrols sometimes stopped to evaluate his objectives.

Dr. Marsh was a member of the Arkansas Native Plant Society, and also of the Arkansas Vascular Flora Committee, which published the “Checklist of the Vascular Plants of Arkansas” in 2006. He was a co-author, with several of his students, on over a dozen papers in the Journal of the Arkansas Academy of Science as well as other journals.

Having retired in 2000, after a career spanning 32 years, Dr. Marsh died 26 July 2010, at the age of 77. He is survived by his former wife, a daughter, a son, and a “god-son” and his wife and their offspring. His academic legacy will be remembered due to his impact on the biology program at Henderson State University, the Academy, the state of botanical knowledge in Arkansas, and the careers of his students.

One of his former students recently named a new species of bryophyte in his honor (Fossombronia marshii, published in Phytologia).

Renn Tumlison, Department of Biology, Henderson State University, Arkadelphia, AR 71999

Henry W. Robison, 9717 Wild Mountain Drive, Sherwood, AR 72120.
In Memoriam: Van Rick McDaniel, 1945-2009

While Dr. Rick McDaniel served as mentor for many Master’s students at Arkansas State University, he also was very active in the Arkansas Academy of Science and Southwestern Association of Naturalists (SWAN). His students were expected to present results of research at meetings of both organizations each year, and there was never a question of whether we would be attending those meetings. As a result, his students became familiar and comfortable with an aspect of professional life that gave us an advantage against other graduates seeking employment or entrance to doctoral programs.

McDaniel was born 29 October 1945 in San Antonio, Texas. After earning both his B.S. and M.S. degrees at Texas A & I, he completed his formal education at Texas Tech University, receiving the Ph.D. in 1973. His doctoral work focused on bats in Central America, and his interest in chiropteran biology fostered studies with several of his graduate students at ASU. Sometimes he was called the “batman of Arkansas.”

Immediately upon completion of his doctoral degree in 1973, Dr. McDaniel became an Assistant Professor of Zoology at ASU, ascended to Associate Professor in 1977 and subsequently full Professor and departmental chair in 1984. During 1997, he entered the ranks of administrators with lengthy titles – beginning with Interim Associate Dean of the College of Arts and Sciences, followed by Associate Dean of the College of Arts and Sciences (1998), Associate Vice President for Academic Affairs (2000), Interim Vice President for Academic Affairs (also 2000), and finally Senior Associate Vice Chancellor for Academic Affairs (2003).

Dr. McDaniel’s list of academic accomplishments is fairly extensive. Between 1969 and 1999, he was an author on 81 publications and articles in a variety of journals and project reports, including 35 papers published in the Proceedings of the Arkansas Academy of Science. During the same period, he was co-author on 108 presentations of research, including 69 made at meetings of the AAS. From 1980 – 1981, he served as newsletter editor for AAS, and served as editor of the Proceedings from 1982–1986.

Work on thesis committees resulted in many of Dr. McDaniel’s presentations and publications. He served on 61 thesis committees (30 of which he chaired), and although his research emphasis dealt with biology of mammals, he also was involved in studies of limnology, plants, protozoans, insects and other invertebrates, and all vertebrate groups. Being a grantee on 31 funded grants for research projects provided financial aid for several students.

Dr. McDaniel spent many hours at his office and with his graduate students. Soon after I became a graduate student at ASU, spark plugs fouled in my truck and he invited me to his house to change them. It was a trap. After getting the engine in running order, I was obligated to play a few games of ping-pong in his garage. He also played racquetball with students, and in the Mammalogy lab there was a nerf basketball goal which was used during study breaks to play contrived word games in which a missed basket provided a letter hint to the genus name of some mystery animal. He loved a tandem style of fishing Ozark creeks with 1-4 students, or fishing from boats in local lakes.

Several students went along on weekend caving trips, just for the sake of exploring a new and strange system. Sometimes a single trip to the unique and biologically unexplored environment would lead to an important and publishable discovery.

Having retired after a career spanning 35.5 years, Dr. McDaniel was playing golf when he suddenly and unexpectedly died 31 July 2009, at the age of 63. He is survived by his wife, three sons, five daughters, and 10 grandchildren. His academic legacy will be remembered due to his impact on Arkansas State University, the Academy, and the careers of his students.

Renn Tumlison, Department of Biology, Henderson State University, Arkadelphia, AR 71999

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In Memoriam: Robert L. Watson, 1934 – 2010

Robert Lee Watson, 75, of Little Rock passed away on Saturday, April 24, 2010. He is survived by his wife of 45 years, Mary Ann, and children Brian Watson and Melanie Kirtley of Little Rock; Kelly Otwell of Maumelle; and five grandchildren, John Thomas, Kate and Emma Otwell, and Allison and Jack Kirtley.

Born on November 8, 1934, in Plainview, Arkansas, Bob graduated from Plainview High School in May 1952, received an associate degree in Agriculture from Arkansas Polytechnic College (now Arkansas Tech University) in 1954, bachelor’s degree in General Agriculture (1956) and master’s degree in Entomology (1963), both from the University of Arkansas, and a Ph.D. in Entomology with minor in Zoology and Ecology from Auburn University in 1968. In undergraduate school Bob received a John Rust Scholarship and graduated with high honors. During graduate studies at Auburn University he was member of the Society of Sigma Xi, received a NASA Fellowship, and the 1966 Henry B. Good Award for outstanding graduate student in the Department of Zoology, Entomology, Fisheries and Wildlife.

In 1953 Bob spent a hot summer in Tallulah, Louisiana as a Field Aid for the U.S. Department of Agriculture and worked as a “cotton scout” at Pine Bluff during the summer of 1955. Bob proudly served his country as a Captain in the U.S. Army from 1956 to 1962 being recalled to active duty during the Cuban Missile Crisis while a master’s student at Fayetteville.

Bob moved to Little Rock in September 1967 when he was appointed an Assistant Professor of Biology at the University of Arkansas – Little Rock. After 33 years of service to the Department and University, Bob retired in 2000. During that time, Bob served as Chairman of the Department of Biology for 19 years from 1973 to 1992 and later as Acting Associate Dean of the College of Sciences for two years. Interviewed in 1986 for the campus publication Faculty Focus, Bob said he pursued the Department Chair position because he was not a strong researcher but felt he could do a good job as chair because dealing with people was one of his strong points. Colleagues James Peck and Dale Ferguson paid Watson praise with Peck saying “I wish every department were as lucky as we are” to have Watson as chairperson because “he’s fair, he’s honest, and he communicates.” Ferguson said “he just bends over backwards to be fair.”

Bob was a member of the Entomological Society of America, American Institute of Biological Science, and the Arkansas Academy of Science where he held the office of President from 1990-91. In June 2010 Bob was honored with the dedication of the Robert L. Watson Entomology Museum located in Fribourgh Hall on the UALR campus.

David A. Saugey, Wildlife Biologist, Jessieville-Winona-Fourche Ranger District, Ouachita National Forest, P.O. Box 189, 8607 Hwy 7 North, Jessieville, AR 71949.
Analysis of Gamma Rays and Cosmic Muons with a Single Detector

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Abstract

In this paper, we report on the construction and upgrade of a 2002 Lawrence Berkeley National Laboratory (LBNL) Quanknet Cosmic Muons Detector. By adapting this model, we modify the electronics and mechanics to achieve a highly efficient gamma-ray and cosmic-ray detector. Each detector module uses a one-inch-thick scintillator, attached to a photomultiplier tube (PMT) and mounted on a solid aluminum frame. A mechanical support was designed to allow flexible positioning between the two modules. The detector uses scintillation to transform passing radiation into detectable photons that are guided toward a photocathode surface of the PMT, triggering the release of photoelectrons that are then amplified to yield measurable electronic signals. The modules were connected to an electronics section that compared the signals from the two PMTs and logically determined if they were coincidence events. A data-collection device was added for faster count rates and to enable counts for extended times ranging from a few hours to days as needed. Count rates were taken at a variety of distances from the radioactive source, ⁶⁰Co (cobalt), which produced two gamma rays and a beta particle. To investigate the isotropic behavior of radiation, two detection modules were adjusted to different angles of rotation with respect to each other, and the coincidence counts were measured. The coincidence counts from the modules set at various angles were consistent throughout the angular spectrum, and only lead shielding visibly reduced the number of counts from the radioactive source. The inverse-square-law behavior of radiation has also been considered. The results were such that the number of counts decreased as a function of increasing distance from the source. Furthermore, positioning the detector to point toward the sky in different orientations, we measured cosmic-ray muon flux as the angle from the vertical was decreased. In doing so, we scanned different patches of the atmosphere. For the optimum operation during the detection phase, we plateaued both PMTs to single out their best operating gain voltage while eliminating false background noise signals. The detector is more efficient and adaptable in collecting both gamma rays and cosmic-ray muon-flux information.

Introduction

The inhabitants of the earth are constantly exposed to radiation that comes in two forms: charged-particle radiation and uncharged radiation. It was realized early on that radiation increased rapidly with altitude, suggesting that it had extraterrestrial origins. This hypothesis was confirmed by Robert Andrews Millikan (Millikan 1947), who gave the radiation the name of Cosmic Rays (CRs). DNA mutation and damage, which are implicated in many cancers and genetic disease, can be caused by high-energy CRs (Francis et al. 2006) therefore making the study and understanding of these cosmic rays very important.

CRs are charged particles, with approximately 89% of these particles being protons that have been accelerated to near the speed of light by unknown mechanisms. The origin and nature of acceleration mechanisms of these particles is one of the oldest unanswered fundamental questions in particle physics and cosmology. The highest energy cosmic rays observed have energies in the range of 10²⁰ eV and thus provide a glimpse of physics and astrophysics at energies unattainable in laboratory experiments (Günter 2001). Through collision processes, the protons interact with nitrogen, oxygen and other atoms in the Earth’s upper atmosphere, and numerous secondary particles are produced, forming CRs showers on earth (Bhattacharjee 2000).

In these high-energy collisions, such as $p + n \rightarrow p + p + \pi^-$ and $p + n \rightarrow p + n + \pi^0$, secondary high-energy pion particles, which belong to the meson family, are produced. Pions decay rapidly, with a mean life of 26 ns for charged pions ($\pi^\pm$) and $10^{-16}$ s for uncharged pions ($\pi^0$). A high-energy (charged) pion decays via weak interactions to muons and neutrinos as $\pi^+ \rightarrow \mu^+ + \nu_\mu$ and $\pi^- \rightarrow \mu^- + \bar{\nu}_\mu$. The muon is an electrically charged particle that is similar to an electron, but has roughly 200 times its...
mass and a lifespan of about 2.2 μs, the second-longest lifetime of all known particles. Muons have two properties that allow them to reach the earth's surface: they decay relatively slowly compared to pions, and they penetrate large amounts of material due to their large energy. Muons, unlike pions, have no strong interaction properties and unlike electrons they are too massive to be significantly deflected by atomic electric fields they may encounter.

The other form of cosmic rays is uncharged, electromagnetic radiation that comes in various forms, from radio waves used in cell phones to gamma rays used in radiation treatments for cancer patients. In the spectrum of electromagnetic radiation, gamma rays have the most energy and the shortest wavelength. Gamma rays are produced in the universe by supernovae explosions, solar flares, neutron stars, black holes, and active galaxies. Gamma-rays coming from space are mostly absorbed by the Earth's atmosphere. The most common means of production of gamma rays for scientists to study is the beta decay of certain isotopes. Radioactive decay is the spontaneous disintegration of a radionuclide, accompanied by the emission of ionizing radiation in the form of alpha or beta particles or gamma rays, which are responsible for the majority of background radiation that all life on earth is exposed to on a daily basis.

The current paper focuses on adapting an otherwise CR detector to detect gamma rays, and improving the efficiency of CR detection. Before the detector was modified to accommodate gamma rays, the gamma rays would penetrate the scintillators with little or no reaction at all. By increasing the thickness of the paddles, the chance of slowing and detecting a gamma ray was achieved. In the following sections, we overview the construction phase of the detector, and describe its basic principle and the plateauing procedure. To ensure the overall consistency and functionality of the machine, we investigated the radiation of gamma rays from an active $^{60}\text{Co}$ source\(^1\), demonstrated how the radiation changes with increased distance from the source, and studied its isotropic behavior and the effects of different shielding on the gamma rays produced, furthermore, we investigated CR muon flux dependence on direction; we do not expect the flux to be isotropic because of atmospheric loss through decay of muons with long tracks. We hope the detector becomes standard physics-laboratory equipment so that the physics students of tomorrow will have a greater tool to investigate the nature of radiation that permeates our world of cosmic origin.

### Materials and Methods

#### i. Adaptation to Previous Model

The LBNL “CR detector” (Collier and Wolfley 2006) was originally built in 2002. It consists of two scintillators, light guides, PMTs, and a circuit board. Unfortunately, it has been limited to only studying CR muons. The research group from Southern Arkansas University used the previous LBNL CR detector as a basis for constructing a more versatile, portable muon detector and an efficient gamma-ray detector. This part was accomplished by adopting thicker EJ-212 scintillators to improve gamma ray efficiency. Rather than cutting scintillation material to fit the window of a PMT, a light guide made of acrylic plastic (Lucite) served as optical medium between the scintillator and PMT. By total internal reflection, the efficiency of detection was improved. In reality, efficiency of light transmission from the scintillator to the PMT window via a light guide depends greatly on the surface area of the optical couplings between the three components. In the case of this modified detector, photons-transmission efficiency was no greater than 33 percent. Without the light guide, and with simply air as a transition medium, decreased efficiency of light transmission would be unavoidable.

In addition, we separated the electronics, and used voltage control for the PMT gain and an external pulse counter with a USB interface connected to a laptop computer. This external pulse counter allowed for an increased number of counts and record time; however, the hardware is fully functional, with a built-in counter (although limited to 60-second counts), but it eliminated the need of an external pulse counter for some types of investigations.

#### ii. Scintillators

A scintillator is a substance that produces light when traversed by charged particles. It relies on the property of materials, such as thallium - activated sodium iodide, which emit light when bombarded with ionizing radiation. We can use this emitted light as a trigger whenever radiation passes through the scintillators. Scintillators can be made from various materials, such as crystals, plastics, and semiconductor materials. We used an EJ-212 plastic scintillator manufactured by Eljen Technology. The scintillator is composed of a polyvinyl toluene base that has been

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\(^1\) $^{60}\text{Co}$ decays to the stable element $^{60}\text{Ni}$, and as it decays it produces a beta particle and two gamma rays with a total energy of 2.5 MeV.
doped with dye molecules, 2-methylnaphthalene (C_{11}H_{11}) (Eljen Technology 2009). This light travels through the scintillator and is channeled to the PMT by total internal reflection. The scintillation efficiency of the scintillators is 10000 photons for every 1 MeV of energy deposited.

iii. Photomultiplier Tubes
The PMTs were connected to the scintillator via an acrylic light guide that was shaped, polished and glued to both the scintillator and PMT glass surface, thus forming a paddle-shaped construction. This unit works on the principle of the famous photoelectric effect first proposed by Einstein.

A PMT consists of an input window, a photocathode, focusing electrodes, an electron multiplier, and an anode usually sealed inside an evacuated glass tube. When a photon of light hits the photocathode of low work function, the photocathode produces an electron, therefore converting photonic signals into measurable electronic signals. The electron-multiplier section consists of dynodes, which amplify the electrons by way of secondary electron emission until there is a sufficient number of electrons to produce a several-hundred-millivolt signal. The detector that we constructed uses a P30CW5 PMT (Hamamatsu 2006) that incorporates a blue-green sensitive bi-alkali photocathode and a multi-stage high-voltage (HV) power supply. This voltage is applied to a chain of dynodes and ranges from 300 V to 1800 V, more than 1000 times the power delivered by the PMT’s power distribution unit. Only photons emitted within the scintillators are desirable for accurate measurements; therefore, we carefully wrapped the scintillators, light guide, and PMT together with light-tight materials that block unwanted visible light (noise) from entering and flooding the sensitive PMT surface.

iv. Electronics Section
The electronics section of the detector processes the pulses from the PMTs and converts them into counts that are displayed on a readout. Another smaller circuit board was designed by the team and incorporated into the electronics section of the detector to adjust the control/gain voltage to the PMTs. The plateauing of the PMTs, which indicates the optimal operating voltage, allows for greater sensitivity with little interference of background radiation. The collection of resistors, capacitors, diodes and integrated circuits compares PMT output pulses against a given voltage. This voltage difference can be as small as 7 mV and still make a detection event. Then the electronic circuit determines, through a series of logic gates, if the pulses from each PMT are close enough in time to call the pulses coincidences. The electronics require that hits in each module occur within $8 \times 10^{-7}$ s to qualify as a count; only then will the electronic circuits advance the counter. The circuit board also features an RC timer that can be set to a given time, chosen to be 1 minute, so that repeated measurements can be taken. This may be a buzzer that is activated each time a hit is registered.

v. External Pulse Counter
The external pulse counter, although not required, allows the CR detector greater flexibility. We used a USB-1208LS personal measurement device with digital and analog inputs and outputs in addition to a counter function. This commercially available plug-and-play device, compatible with TracerDAQ software, allowed for data from the CR detector to be fed directly to a computer, and enabled event counting that may require long time measurements or that may run too fast to count via the onboard counter. During the course of our data collection the USB interface permitted overnight recording of events when required. The computer program supplied with the USB pulse counter was used to record all the data from the pulse counter.

vi. Methods
Once the detector was fully functional and the research team had tested it, a series of calibration procedures was performed. These procedures consisted of both single PMT pulse rates and coincidence rates to...
calibrate the detectors for muons and gamma rays. Each sample of single counts was taken in one minute intervals and ranged from 0 counts at the lowest setting of control voltage to over 60000 counts at the highest setting. The large variation of counts with respect to the PMT operating voltage produced plateau regions.

When observing the coincidental count rates, we set one PMTs at a fixed control voltage and adjusted the rate of the other PMT. As illustrated in Fig. 2, when the control voltage of one PMT was set at 0.54 V and the other PMT was adjusted through the range of control voltage settings, a long plateau region was observed.

Once the plateau regions were identified, the detector modules were positioned at different spacings and we recorded the number of coincidence counts that the radioactive sources produced. We also used different types of shielding, such as lead, aluminum and wood, to observe how well each piece of shielding worked, further examining the overall consistency and functionality of the detector. The detector modules were then set at 90-degree angles in relation to each other and recorded the number coincidence counts in the presence of a radioactive source as in Fig. 3.

To better understand muons-flux direction, we measured the number of coincidence counts versus detector orientation. The initial configuration was such that the detector pointed vertically; the angle was then varied. One set of measurements were taken in the laboratory and another set was taken in the field.

Results

i. Cobalt 60

When testing the cobalt-60 source, both modules were aligned sideways and their distance from the source varied (Fig. 4). The number of counts was plotted as a function of distance from the source. The results are shown in Fig. 5.

An angular measurement was also taken with one of the PMT tilted on its side and the other PMT
Figure 4. Experimental setup examining the inverse-square-law of radiation. The two scintillators were kept at a fixed position, while the distance $d$ from the source varied.

Figure 5. $Y = 1.4 \times 10^6 d^{-2.24}$ This is the function for the graph displaying Counts vs. Distance (d) of the radiation-attenuation law. The graph refers to gamma rays produced by cobalt-60.

Figure 6. Graph illustrating the uniformity of counts. Result show that gamma rays from $^{60}$Co are emitted isotropically. Source-detector configuration used corresponds to that of Fig. 3.

Figure 7. Count of CR flux vs. the angle from horizontal. A 90° angle corresponds to the detector sitting straight up, while 0° is when it points to the horizon (see Fig. 1).

revolved around different angles. Coincidence counts were taken in the presence of a $^{60}$Co source.

In testing different types of shielding, a measurement with no shield was taken 25.4 cm from the cobalt source and the PMT; and a record of 37051 counts per minute was measured. Next a 0.3175-cm aluminum shield was placed between the source and PMT and a count of 35828 was registered. Next, the aluminum shield was replaced with a 5.08-cm wood block and a count of 35630 was detected. After that a single and then another 6.35-cm lead acid battery was added between the source and the detector and counts of 22826 and 16828 were recorded.

ii. Cosmic-Ray Muons

The PMTs are very sensitive and generate their own noise. This is largely due to thermal energy causing an electron to be ejected, which then excites several other electrons in the neighboring plates, triggering a false signal. To minimize the noise, a plateauing procedure was performed as described earlier for each PMT module. The procedure was done while looking for coincidence events, which revealed a plateau range around one volt without major disruption in the number of counts between different control voltages.

After the PMTs were plateaued, they were set to a vertical configuration and then tilted to determine the count rates at various degrees from horizontal (Fig. 7).
Discussion and Conclusion

The $^{60}$Co source produced results similar to the expected $\frac{1}{r^2}$ but not exactly. The experimental results were not as exact because the inverse square law is derived for an ideal point source subtended by a spherical-detection aperture, whereas the detector at hand uses rectangle-shaped scintillators. Due to its rectangular geometry, we expect the scintillator to lose some of the gamma rays (Taylor et al. 2010) that would have otherwise contributed to the inverse square law, explaining the apparent additional 0.24 attenuation in our findings. This is particularly apparent as our observation matches closely the $\frac{1}{r^2}$ dependence when the source gets closer to the PMT module. The angular investigation, however, agrees with the common knowledge that the gamma rays emitted from the $^{60}$Co source are isotropic as they leave the source. Our findings are such that the detection rate was the same when measurements were taken along axes in any direction. The CR experiments verify previous experiments demonstrating that as the PMT modules are moved closer together, the solid angle gets larger and the number of detected CRs increases. Detailed analysis of solid-angle dependence will be reported elsewhere. The CR angular measurements suggest that, since the muon flux decreases as the two stacked modules are moved away from a vertical arrangement, the muons mostly come from above and shower straight down to Earth, rather than showering at some inclination angle. Another possible reason for this recorded attenuation in flux when the PMT's axis is closer to horizontal, is that more of the muons would have decayed because of longer trips in the atmosphere to get to the detector when it points sideways.

The end of this project is just the beginning for these detectors. Through the experimental process, the equipment underwent many repair procedures including the re-cementing of the light guides to the photomultipliers. Several of these came loose through the use of the modules. The mechanical device needs to be improved to hold the scintillator and light guide to the PMT. The mechanism built to separate the two modules from each detector is difficult to adjust and bends, not allowing the modules to be held together in perfect alignment.

Once these issues are resolved, the detector can be used to train future physics students in the detection of CR muons and gamma rays. Investigating the radiation-flux dependence on altitude in the state of Arkansas will greatly contribute to the scientific knowledge about the state; this will be explored in future work. The greater collection of data that will be accumulated by students over the next several years with these detectors will give other students and faculty of other disciplines a chance to understand the processes that are involved all around them. We hope that these detectors will not only serve physics undergraduates, but rather be used as a tool to incite the imagination of high-school students who are interested in physics.

Acknowledgments

We would like to thank everyone in association with the building of the detector, Dr. Helmuth Spieler, Dr. Howard Matis and Dr. James Siegrist. Special thanks to LBNL, Center for Science and Engineering Education of LBNL, Physics Division of LBNL. This work has been supported by the Department of Energy and National Science Foundation.

Literature Cited


Synthesis and Characterization of Ruthenium Complexes Containing Chlorophenanthroline and Bipyridine

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Abstract

The divalent ruthenium polypyridine complexes hold promise as efficient photocatalysts for solar-energy conversion schemes. This paper deals with the synthesis and spectroscopic investigation of ruthenium polypyridine complexes, which may be useful as photosensitizers. The homoleptic ruthenium(II) complex \( \text{Ru(Cl-phen)}_2(\text{PF}_6)_2 \) (where Cl-phen = 5-chloro-1,10-phenanthroline), and heteroleptic ruthenium(II) complexes \( \text{Ru(Cl-phen)}_2(\text{bpy})(\text{PF}_6)_2 \) and \( \text{Ru(Cl-phen)}(\text{bpy})_2(\text{PF}_6)_2 \) (where bpy = 2,2'-bipyridine) have been prepared by following the standard synthetic procedure. Silica and alumina column chromatographies were used to purify the compounds. Mass spectroscopy, nuclear magnetic resonance (nmr) spectroscopy, and elemental analysis were used to confirm the identity and the integrity of the complexes. Absorption and emission spectroscopies in addition to cyclic voltammetry were used to investigate the properties of these complexes. The absorption spectra of all complexes consist of a series of absorption bands in the ultraviolet and visible regions. All three complexes show a strong emission band in the visible region. Cyclic-voltammetric investigations indicate that the chloro substitution either has little impact on the redox properties of the complexes or alters the redox properties in an advantageous manner.

Introduction

Photosynthesis is the process that converts carbon dioxide and water into glucose and oxygen by using the energy from sunlight in the presence of chlorophyll (Lawlor 1993). Photosynthesis is a vital process in maintaining life on Earth. The normal level of oxygen in the atmosphere is maintained by photosynthesis, and all life depends on this process directly or indirectly. Only a very small fraction of the huge amount of available solar energy is used by green plants in photosynthesis. During photosynthesis, green plants convert solar energy into chemical energy by splitting \( \text{H}_2\text{O} \) into \( \text{H}_2 \). For the last two decades, there has been an intense interest in designing molecular systems that mimic photosynthesis. The strategy has been to design a molecular assembly that will absorb visible light, initiate an electron-transfer process, and ultimately use the solar energy to extract hydrogen for fuel from water (Kalyanasundaram 1987, Parmon and Zamarev 1989).

Hydrogen is one of the most attractive fuels because it does not produce any carbon dioxide or carbon monoxide during combustion, and the only combustion product is water. The energy of a substantial fraction of the sun’s spectral output is thermodynamically sufficient to accomplish splitting of \( \text{H}_2\text{O} \) into \( \text{H}_2 \) and \( \text{O}_2 \). A synthetic photocatalytic system that can produce hydrogen by the reduction of water is shown in Scheme 1. Several issues such as proper choice of sensitizer, excited-state lifetime, back electron transfer, and suitable redox properties need to be resolved to make Scheme 1 practical. Many attempts have been made (Ramamurthy 1991) to overcome these problems, and the most promising results are obtained by using polypyridine complexes of divalent ruthenium (Jures et al. 1988, Kalyanasundaram 1982).

![Scheme 1. Photocatalytic system for splitting of water (S = sensitizer, A = acceptor, BET = back electron transfer, CAT = catalyst).](image-url)

The long-range goal of our research program is to develop new molecular systems that mimic...
photosynthesis. Ruthenium polypyridine complexes have been investigated for use in artificial photosynthesis. It has been documented that ruthenium polypyridine complexes have potential use as efficient photoinitiators in electron-transfer studies (Rillema et al. 1983, Ernst and Kaim 1989, Kawanishi et al. 1989, Lever 1990, Winkler et al. 1982). This has prompted us to further investigate the properties of such complexes. This study has focused on tuning the redox and excited-state properties of ruthenium(II) polypyridine complexes by ligand substitution. It is very difficult to determine what ligand modifications will produce the best combination of excited-state and redox properties. This project is designed to test several ruthenium(II) complexes, homoleptic and heteroleptic with different combinations of ligands, in order to determine how the essential properties are affected.

In this paper, we report efficient synthetic methods for the preparation of Ru(Cl-phen)$_3$(PF$_6$)$_2$, Ru(Cl-phen)$_2$(bpy)(PF$_6$)$_2$, and Ru(Cl-phen)(bpy)$_2$(PF$_6$)$_2$ (where Cl-phen = 5-methyl-1,10-phenanthroline and bpy = 2,2'-bipyridine) complexes (cationic forms are shown in Figure 1). The complexes were purified by column chromatography. The identity and the integrity of the complexes were confirmed by elemental analysis, mass spectroscopy, and nmr spectroscopy. UV-vis absorption and emission spectroscopic methods and cyclic-voltammetric methods were used to investigate the properties of these complexes. Spectroscopic, photophysical, and electrochemical studies document the fact that inherently favorable properties of the parent complexes are not substantially altered by these ligand substitutions.

Figure 1. Schematic representation of the prepared complexes.

Materials and Methods

**Chemicals**

RuCl$_3$·3H$_2$O, 5-chloro-1,10-phenanthroline (Cl-phen), 2,2'-bipyridine (bpy), NH$_4$PF$_6$, LiCl, alumina, and high-purity silica gel were purchased from the Aldrich Chemical Company. All the chemicals were used as purchased without further purification. All solvents used were reagent grade or better.

**Measurements**

Elemental analysis was performed by Columbia Analytical Services, Tucson, AZ. Electrospray ionization mass-spectral (ESI-MS) measurements were performed with a Bruker Esquire LCMS by the Arkansas State Wide Mass Spectrometry Facility at University of Arkansas, Fayetteville. All the samples were dissolved in acetonitrile and were injected directly with a flow rate of approximately 50 µL min$^{-1}$ with nitrogen nebulizing gas. $^1$H-NMR spectra were recorded using a Bruker 400 MHz spectrometer at the University of Arkansas, Fayetteville. Spectra were measured in CD$_3$CN in δ ppm referenced to tetramethylsilane (Me$_4$Si). Electronic absorption spectra were obtained with a Shimadzu model UV-2501 PC Uv-vis recording spectrophotometer using a 1-cm quartz cuvette. Spectra were obtained in the absorbance mode. The electronic absorption spectra of all the complexes were measured in acetonitrile solution. The electronic emission spectra were obtained with a PerkinElmer Model LS 55 luminescence spectrometer at 450nm λ$_{exc}$. The emission spectra of all three complexes were measured in acetonitrile solution at room temperature. Cyclic voltammetry was performed with a CH Instruments Electrochemical Analyzer at the University of Arkansas, Fayetteville.
The working electrode was a 2-mm-diameter platinum-disk electrode, the auxiliary electrode was platinum wire and the reference electrode was a saturated calomel electrode from CH Instruments. Cyclic voltammograms were recorded in 0.1 M (Bu₄N)(PF₆) (tetrabutylammonium hexafluorophosphate) in CH₃CN.

**Preparation of Compounds**

Ru(Cl-Phen)₃(PF₆) was prepared by a method previously developed in our laboratory (Bhuiyan et al. 2009); our method is a modification of a method developed by Walker et al. (2004). The reaction involves the substitution of 5-chloro-1,10-phenanthroline for a bipyridine ligand. The compound was prepared by the reaction of RuCl₃·3H₂O (1 mmol) and Cl-phen (4 mmol) in 50 mL ethylene glycol under an argon atmosphere. The reaction mixture was refluxed for 4 hours, during which there was a color change from dark black to bright orange. The resulting solution was then cooled to room temperature and filtered. The product was precipitated as a PF₆ salt by adding a saturated solution of aqueous ammonium hexafluorophosphate (NH₄PF₆). This mixture was refrigerated overnight to enhance the precipitation, and the precipitate was collected by vacuum filtration. The precipitate was washed with cold water to remove excess NH₄PF₆, and was finally washed with diethyl ether. After the precipitate was dried in a desiccator, 0.5687 g product was obtained. The crude compound was purified by column chromatography using a silica-gel stationary phase and acetonitrile as an eluent. The yield was 0.3926 g (80% yield).

Ru(Cl-phen)(bpy)₂(PF₆)₂ was also prepared in a two-step process. The precursor complex, cis-Ru(bpy)₂Cl₂, was prepared by following the literature method proposed by Sullivan et al. (1978) with a slight modification. RuCl₃·3H₂O (1 equivalent), bpy (2 equivalents), and LiCl (0.1 equivalent) were refluxed in 50 mL DMF (dimethyl formamide) for 6-7 hours with constant stirring under argon. After cooling to room temperature, 125 mL of acetone was added into the reaction mixture and stirred for a few minutes. The resulting mixture was placed in a freezer at -5 °C overnight. Microcrystalline black precipitate was collected by vacuum filtration. The product was washed several times with cold water and finally with diethyl ether and stored in a desiccator. The identity of the prepared precursor complex was confirmed by absorption spectroscopy.

Ru(Cl-phen)(bpy)₂(PF₆)₂ was prepared from the reaction of Ru(bpy)₂Cl₂ (0.5 mmol) and Cl-phen ligand (1.0 mmol). The materials were dissolved in 50 mL H₂O and refluxed 5 hr under argon while stirring. During the reaction, the color of the solution changed from black to brown to blood red. The solution was cooled to room temperature and filtered. Saturated aqueous NH₄PF₆ was added to the filtrate to precipitate the product as a PF₆ salt, and the solution was left in the refrigerator overnight. The orange precipitate was collected by vacuum filtration and washed with cold water and diethyl ether. The product was vacuum dried and placed in a desiccator. The product was purified by silica-gel column with CH₃CN as an eluent. The first band was collected and added dropwise to diethyl ether to reprecipitate. Yield was 0.5180 g (typically ~70% yield).

**Results and Discussion**

All three complexes, Ru(Cl-phen)₃(PF₆)₂, Ru(Cl-phen)(bpy)(PF₆)₂, and Ru(Cl-phen)(bpy)₂(PF₆)₂, were prepared by following the method previously developed in our laboratory (Bhuiyan et al. 2009). The synthetic method for Ru(Cl-phen)(PF₆)₂ compound involves only one step, which is based on the pioneering work of Walker and coworkers (2004). This is a very simple, rapid, and convenient method that requires only a slight excess of...
ligand. Thin-layer chromatography (TLC) indicated the presence of trace impurities in the complex, which we than removed by column chromatography. The heteroleptic complexes Ru(Cl-phen)(bpy)(PF$_6$)$_2$ and Ru(Cl-phen)(bpy)$_2$(PF$_6$)$_2$ were prepared by a two-step processes. In the first step, the precursor complexes Ru(bpy)Cl$_2$ were prepared according to published methods (Krause 1977, Sullivan et al. 1978). Sufficiently pure precursor complexes were obtained and no further purification was necessary. The second step involved the reaction of the previously prepared precursor complexes and additional Cl-phen ligand. This type of procedure is common for mixed-ligand complexes (Bhuiyan et al. 2009, Bhuiyan et al. 2008, Bhuiyan 2008, Bhuiyan and Kincaid 1999). Thin-layer chromatography indicated that all three compounds were slightly contaminated. We used the most common purification method of column chromatography on silica with acetonitrile as an eluent compounds were prepared by a two-step process. In the first step, the precursor complexes Ru(Cl-phen)(bpy)(PF$_6$)$_2$ and Ru(Cl-phen)(bpy)$_2$(PF$_6$)$_2$ were prepared according to published methods (Krause 1977, Sullivan et al. 1978). Sufficiently pure precursor complexes were obtained and no further purification was necessary. The second step involved the reaction of the previously prepared precursor complexes and additional Cl-phen ligand. This type of procedure is common for mixed-ligand complexes (Bhuiyan et al. 2009, Bhuiyan et al. 2008, Bhuiyan and Kincaid 1999). Thin-layer chromatography indicated that all three compounds were slightly contaminated. We used the most common purification method of column chromatography on silica with acetonitrile as an eluent for all three complexes.

The calculated and experimental results of the elemental analysis of all three complexes are given in Table 1. The experimental results are in close agreement with the calculated results for all three complexes, which confirms the identity of the prepared complexes.

Table 1. The experimental results are in close agreement with the calculated results for all three complexes. The calculated molar masses for the complexes are 745.0 g/mol [Ru(Cl-phen)]$^{2+}$, 686.6 g/mol [Ru(Cl-phen)]$^2$, and 628.1 g/mol [Ru(Cl-phen)]$^3$]$. The electro spray mass spectrometry of the complexes showed a consistent fragmentation pattern (Figure 2). The experimental isotopic patterns are consistent with the calculated isotopic patterns.

Each spectrum showed the molecular-ion peak. The molecular-ion peaks appear at m/z (mass/charge) = 372.8 (trace A), m/z = 343.3 (trace B), and m/z = 313.9 (trace C). From the isotopic patterns, it was confirmed that each ion has an overall charge of 2+, so the experimental molar masses are 745.6 g/mol (trace A), 686.6 g/mol (trace B), and 627.8 g/mol (trace C) for Ru(Cl-phen)]$^{2+}$, Ru(Cl-phen)]$^2$, and Ru(Cl-phen)]$^3$] respectively. The experimental molar masses are in very good agreement with the calculated molar masses, which confirms the identity and the integrity of the compounds.

The aromatic part of the $^1$H NMR spectrum of Ru(Cl-phen)]$^2$ is shown in Figure 3. This spectrum exhibits magnetic inequivalence because of the presence of a chloro group on the phenanthroline ligand. The proton peak assignments are made by comparing with the reported spectrum of a cyano-substituted phenanthroline complex (Mellace et al. 2004). H$_5$ and H$_7$ are the most affected protons because of the proximity to the electronegative chloro group and are shifted downfield. H$_6$ has no neighboring protons and therefore appears as a singlet at 8.43 ppm. H$_3$ and H$_8$, and H$_2$ and H$_9$ are shifted upfield because of nitrogen coordination to the ruthenium(II) ion. As a consequence of coordination and the π back-bonding effect, those protons are strongly shielded and shifted upfield.

The integration for each signal is shown at the bottom part of Figure 3, and each of them is consistent with the presence of one proton. The NMR spectra become complicated for mixed-ligand complexes because of the overlap of two ligand bands and are not shown here.

![Figure 2](https://scholarworks.uark.edu/jaas/vol64/iss1/1)

Electronic absorption spectra of all the prepared complexes are shown in Figure 4. The solid-line spectrum is for Ru(Cl-phen)]$^{2+}$ (trace A), the dotted line is for Ru(Cl-phen)]$^2$ (trace B), and the dashed line is for Ru(Cl-phen)]$^3$ (trace C). The absorption spectra of the complexes are very similar to methyl-substituted complexes previously reported by Bhuiyan et al. (2009). All the spectra consist of a series...
Synthesis and Characterization of Ruthenium Complexes Containing Chloro-Phenanthroline and Bipyridine

Table 1. Comparison of calculated and experimental results of elemental analysis of the prepared complexes.

<table>
<thead>
<tr>
<th>Formula</th>
<th>RuC₃₆H₂₁N₆Cl₁₂P₁₂F₁₂</th>
<th>RuC₃₄H₂₂N₆Cl₁₂P₁₂F₁₂</th>
<th>RuC₃₂H₃₂N₆Cl₁₂P₁₂F₁₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elements</td>
<td>%C</td>
<td>%H</td>
<td>%N</td>
</tr>
<tr>
<td>Calculated</td>
<td>41.78%</td>
<td>2.05%</td>
<td>8.12%</td>
</tr>
<tr>
<td>Experimental</td>
<td>41.62%</td>
<td>2.47%</td>
<td>8.56%</td>
</tr>
</tbody>
</table>

of absorption bands in the UV and visible regions. A very strong transition at 266 nm is assigned to a spin-allowed ligand-centered π–π* transition of the Me-phen ligand, and a 285 nm peak is assigned to a π–π* transition of bpy ligand (Kalyanasundaram and Nazeeruddin 1990). Ru(Cl-phen)₃²⁺ does not contain any bpy ligand, and the 285 nm absorption band is totally absent in the spectrum (trace A). Ru(Cl-phen)(bpy)²⁺ exhibits a 285 nm band as a weak shoulder because of the presence of one bpy ligand (trace B), and Ru(Cl-phen)(bpy)²⁺, with two bpy ligands, exhibits a strong band at 285 nm (trace C). The broad, relatively intense visible band at 450 nm is assigned to a metal-to-ligand charge-transfer (MLCT) transition by comparing with other ruthenium(II) polypyridine complexes (Denti et al. 1990). The higher-energy shoulder observed is assigned to a second MLCT transition.

The room-temperature emission spectra of all the complexes are shown in Figure 5. The excitation wavelength was determined by scanning the excitation spectra at a fixed emission wavelength. The excitation wavelength is 450 nm for all three complexes. The solid line is for Ru(Cl-phen)₃²⁺ (trace A), the dotted line is for Ru(Cl-phen)(bpy)²⁺ (trace B), and the dashed line is for Ru(Cl-phen)(bpy)²⁺ (trace C). The electronic emission spectra of the complexes exhibit strong emission bands at 587 nm for Ru(Cl-phen)₃²⁺, at 590 nm for Ru(Cl-phen)(bpy)²⁺, and at 597 nm for (Ru(Cl-phen)(bpy)²⁺. All three complexes exhibit a single emission band, which confirms the purity of the prepared complexes. The emission spectra of the complexes are very similar to methyl-substituted complexes previously reported by Bhuiyan et al. (2009). As for other polypyridine complexes of Ru(II), these luminescence bands have been assigned as the phosphorescent process ³MLCT (triplet metal-to-ligand charge transfer) → ¹GS (singlet ground state) (Lytle and Hercules 1969, Bhuiyan and Kincaid 2001).

Figure 3. ¹H NMR spectrum of Ru(Cl-phen)₃²⁺ in the aromatic region between δ 7.5 ppm and 9.0 ppm in CD₃CN (TMS reference).

Figure 4. Electronic absorption spectra of the prepared complexes: Ru(Cl-phen)₃²⁺ (trace A); Ru(Cl-phen)(bpy)²⁺ (trace B); and Ru(Cl-phen)(bpy)²⁺ (trace C).

Figure 5. Electronic emission spectra of the complexes.
of another bpy ligand. This observation is consistent with the previously reported spectra of similar ruthenium(II) polypyridine complexes (Bhuiyan et al. 2009).

Cyclic voltammograms of all the prepared complexes are shown in Figure 6. The solid line is for Ru(Cl-phen)$_3^{2+}$ (trace A), the dotted line is for Ru(Cl-phen)$_2$(bpy)$_2^{2+}$ (trace B), and the dashed line is for Ru(Cl-phen)(bpy)$_2^{2+}$ (trace C). All three complexes exhibit a single reversible electrochemical wave over the range examined. Table 2 summarizes the potential for the Ru(II) to Ru(III) oxidation. For each of the complexes, the potential corresponds to oxidation of ruthenium(II) to ruthenium(III). The potentials are $E_{1/2}$ = +1.38 V (trace A), $E_{1/2}$ = +1.34 V (trace B), and $E_{1/2}$ = +1.32 V (trace C). The single wave for each complex confirms the purity of the prepared complexes. The presence of bpy ligands shifts the wave to lower potentials. This phenomenon indicates the energy of $\pi^*$ energy levels are lowered by the presence of Cl-phen ligand, and ruthenium complexes with Cl-phen ligands are poor reductants but better oxidants (Rillema et al. 1987).

Conclusions

The present work describes efficient synthetic methods for the preparation of Ru(Cl-phen)$_3$(PF$_6$)$_2$, Ru(Cl-phen)$_2$(bpy)(PF$_6$)$_2$, and Ru(Cl-phen)(bpy)$_2$(PF$_6$)$_2$ complexes. Elemental analysis, mass spectroscopy, and nmr spectroscopy confirm the identity and structural integrity of the prepared complexes. Absorption, emission, and cyclic voltammetric results were very comparable with the reported results for similar compounds. It was observed that the inherently favorable photophysical properties are not substantially altered by the ligand substitution. These complexes are attractive precursors for the construction of high-charge ruthenium complexes by nickel-catalyzed coupling reactions, and presently we are in the process of making the dimer complexes.

Acknowledgments

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Literture Cited

Bhuiyan AA, S Kudo, C Wade and RF Davis. 2009.


The Effectiveness of Weight Control through Weight Watch Programs

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Abstract

Linear probability estimation and survey data are employed to quantify the influence of the lifestyles of individuals on the change in their body mass index (BMI). The analysis also explores the effects of demographic characteristics (age, gender, and ethnicity) in weight management. Results suggest evidence of association between changes in lifestyle and changes in the BMI of individuals.

Introduction

Obesity is one of the most serious health conditions facing adults and the youth alike in the U.S. today, and evidence suggests that the threat is worsening rapidly, reaching epidemic proportions. Among adults aged 20 or older, the prevalence of overweight rose from 55.9\% to 64.5\% in 1988-1994 to 1999-2000 and that of obesity rose from 22\% to 30.5\% for the same period (Flegal et al. 2002). Among children aged 6 through 19 years, 65.1\% were overweight or obese and 4.9 \% extremely obese in 2001-2002 (Hedley et al. 2004). A major concern about overweight and obesity is the serious risks of obesity-related chronic conditions such as type II diabetes, coronary heart disease, hypertension, gallbladder disease, breast cancer, endometrial cancer, colon cancer, and osteoarthritis. All these conditions are known to considerably reduce the quality of life, increase morbidity and mortality, and lead to premature death (Arvaniti and Panagiotakos 2008). Furthermore, economic costs associated with overweight and obesity is estimated at over $99.2 billion per year and constitutes a substantial burden on the U.S. healthcare system (Allison et al. 1999).

As the prevalence of overweight and obesity is increasing, so is the awareness of their health consequences among the public. This growing consciousness is translated by the spread of weight-watch programs aimed at establishing healthy lifestyles that will reduce the weight of participants. The scientific knowledge of the relationship between diet and health is being increasingly used to study the quality of diet (Guthrie and Morton 2000). Although inconclusive, many previous studies suggest the existence of a significant relationship between lifestyle and weight status of adults and children alike. Those findings have important policy implications because provisions of health and nutritional information to communities may help people to establish healthy eating habits and lifestyles, which are likely to contribute to the reduction in weight problems. Few studies, if any, have attempted to link participation in weight-loss programs to reduction in Body Mass Index (BMI) of participants. More research is needed to determine what specific lifestyles and diet habits would augment clinical care in reducing and controlling weight gain. Specifically, there is a need to assess the effectiveness of some weight-watch programs in relation to the instruction content and weight reduction of participants. It is logical to expect that the more knowledgeable and well-informed people are about the nutrient content of food items and health consequences of various diets, the better they can translate this information in planning household meals, implying healthier diets for household members.

This study intends to address this need by supplementing the literature an analysis of collected data that contributes to understanding factors that may influence the likelihood and extent of weight loss. Thus, the primary objective of the study is to identify demographic factors and lifestyles that influence or determine weight loss. Specifically, the study intends to (1) examine and assess the likelihood of participation in weight loss programs reducing the Body Mass Index, (2) estimate and quantify the effect of selected demographic factors, food consumption patterns, and physical exercise habits. The results should provide important policy implications to public health officials with respect to the development of nutritional education, and information delivery if needed, as the potential health benefits from reduction
in overweight and obesity are of considerable public health importance.

**Definition of Obesity**

Obesity refers to an excessive accumulation of fat in adipose tissue, which is the form of excess energy stored by the body. It results from a positive balance of body energy: that is, when total-calorie-intake exceeds total expenditure (Smith 1999). This excess of body fat is characterized by an increase in body weight. As a result, the terms overweight and obesity are used somewhat interchangeably in the literature. A commonly used measure of overweight and obesity is a weight-to-height ratio called the Body Mass Index (BMI), which is defined as body mass in kilograms divided by the squared height in meters. Using the BMI, the National Heart, Lung, and Blood Institute (NHLBI) (Rolfes et al. 2009) provides cutoff guidelines to define obesity in adults as shown in Table 1.

Table 1: Weight status definitions for adults

<table>
<thead>
<tr>
<th>NHLBI Classification</th>
<th>BMI Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underweight</td>
<td>BMI &lt; 18.5</td>
</tr>
<tr>
<td>Normal weight</td>
<td>18.5 ≤ BMI &lt; 25</td>
</tr>
<tr>
<td>Overweight</td>
<td>25 ≤ BMI &lt; 30</td>
</tr>
<tr>
<td>Obese class 1</td>
<td>30 ≤ BMI &lt; 35</td>
</tr>
<tr>
<td>Obese class 2</td>
<td>35 ≤ BMI &lt; 40</td>
</tr>
<tr>
<td>Obese class 3</td>
<td>BMI ≥ 40</td>
</tr>
</tbody>
</table>

**Conceptual framework**

The examination of the relationship between the lifestyles of individuals and their Body Mass Index (BMI) is an empirical question that can be studied in the context of available data. The data used in this study was collected through a survey described in the next section. However, even the most thoroughly designed data gathering effort requires a strong cooperation from all subjects of the study to share the relevant information accurately.

**Data Specifications**

Data used in this study was collected using a survey questionnaire. The subjects of the study included a well-diversified group of students, faculty, and staff enrolled in the SAU weight-watch program. Participants in the weight-watch program all shared a common goal: to reduce their weight by adopting healthy lifestyles. All participants were required to attend weekly educational classes on healthy lifestyles, including nutrients and calorie content of various food groups, exercising, etc. Participants were also required to get weighed at the SAU nursing center once a week to keep track of individual and collective progress. The complete list of data collected is shown on Table 2 below. However, not all of the collected variables were used for analysis.

**The empirical model**

The following model that we applied is aimed at estimating the change in BMI equation:

\[ Y = X\beta \]

where \( Y \) is a vector of dependent variables defined as the change in the BMI of participants, as follows.

\[ y = \frac{W_1 - W_2}{H^2} \]

\( W_1 \) is a vector of the weight of participants at the beginning of the program in kilograms

\( W_2 \) is a vector of the weight of participants at the end of the program in kilograms

\( H \) is a vector of the height of participants in meters

\( X \) is a vector of independent variables used in the estimation of \( Y \).

\( \beta \) is the vector of coefficients to be estimated. A positive coefficient signifies that corresponding independent variable contributes to the increase of the BMI of individuals. A negative coefficient signifies that corresponding variable contributes to the reduction of the BMI of individuals.
<table>
<thead>
<tr>
<th>Dependent variables</th>
<th>Measure or description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>In years</td>
</tr>
<tr>
<td>Gender</td>
<td>Male =0; Female =1;</td>
</tr>
<tr>
<td>Ethnicity</td>
<td>White: Yes =1; No =0;</td>
</tr>
<tr>
<td></td>
<td>Black: Yes =1; No =0;</td>
</tr>
<tr>
<td></td>
<td>Hispanic: Yes =1; No =0;</td>
</tr>
<tr>
<td></td>
<td>Asian: Yes =1; No =0;</td>
</tr>
<tr>
<td>Height</td>
<td>Height in number of feet and inches</td>
</tr>
<tr>
<td>Weight</td>
<td>Weight in pounds</td>
</tr>
<tr>
<td>Pre-existing health condition if any</td>
<td>For any health condition Yes =1; No =0;</td>
</tr>
<tr>
<td>Number of times of exercise per week</td>
<td>Number of times of exercise per week per week</td>
</tr>
<tr>
<td>Average time spent each exercise session</td>
<td>Number of minutes per exercise session</td>
</tr>
<tr>
<td>Average hours of sleep per day</td>
<td>Average number of hours of sleep per day</td>
</tr>
<tr>
<td>Experiencing stress</td>
<td>Not at all = 1</td>
</tr>
<tr>
<td></td>
<td>Rarely = 2</td>
</tr>
<tr>
<td></td>
<td>Often = 3</td>
</tr>
<tr>
<td></td>
<td>Very often = 4</td>
</tr>
<tr>
<td>Change in consumption of soft drinks</td>
<td>Considerably decreased = 1</td>
</tr>
<tr>
<td></td>
<td>Slightly decreased = 2</td>
</tr>
<tr>
<td></td>
<td>Stayed the same = 3</td>
</tr>
<tr>
<td></td>
<td>Slightly increased = 4</td>
</tr>
<tr>
<td></td>
<td>Considerably increased = 5</td>
</tr>
<tr>
<td>Change in consumption of alcoholic beverages</td>
<td>Considerably decreased = 1</td>
</tr>
<tr>
<td></td>
<td>Slightly decreased = 2</td>
</tr>
<tr>
<td></td>
<td>Stayed the same = 3</td>
</tr>
<tr>
<td></td>
<td>Slightly increased = 4</td>
</tr>
<tr>
<td></td>
<td>Considerably increased = 5</td>
</tr>
<tr>
<td>Change in consumption of carbohydrates</td>
<td>Considerably decreased = 1</td>
</tr>
<tr>
<td></td>
<td>Slightly decreased = 2</td>
</tr>
<tr>
<td></td>
<td>Stayed the same = 3</td>
</tr>
<tr>
<td></td>
<td>Slightly increased = 4</td>
</tr>
<tr>
<td></td>
<td>Considerably increased = 5</td>
</tr>
<tr>
<td>Change in consumption of vegetables</td>
<td>Considerably decreased = 1</td>
</tr>
<tr>
<td></td>
<td>Slightly decreased = 2</td>
</tr>
<tr>
<td></td>
<td>Stayed the same = 3</td>
</tr>
<tr>
<td></td>
<td>Slightly increased = 4</td>
</tr>
<tr>
<td></td>
<td>Considerably increased = 5</td>
</tr>
<tr>
<td>Change in consumption of red meat</td>
<td>Considerably decreased = 1</td>
</tr>
<tr>
<td></td>
<td>Slightly decreased = 2</td>
</tr>
<tr>
<td></td>
<td>Stayed the same = 3</td>
</tr>
<tr>
<td></td>
<td>Slightly increased = 4</td>
</tr>
<tr>
<td></td>
<td>Considerably increased = 5</td>
</tr>
<tr>
<td>Change in consumption of water</td>
<td>Considerably decreased = 1</td>
</tr>
<tr>
<td></td>
<td>Slightly decreased = 2</td>
</tr>
<tr>
<td></td>
<td>Stayed the same = 3</td>
</tr>
<tr>
<td></td>
<td>Slightly increased = 4</td>
</tr>
<tr>
<td></td>
<td>Considerably increased = 5</td>
</tr>
</tbody>
</table>
Table 2: Dependent variables used in the study, continued

<table>
<thead>
<tr>
<th>Dependent variables</th>
<th>Measure or description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change in consumption of white meat</td>
<td>Considerably decreased = 1</td>
</tr>
<tr>
<td></td>
<td>Slightly decreased = 2</td>
</tr>
<tr>
<td></td>
<td>Stayed the same = 3</td>
</tr>
<tr>
<td></td>
<td>Slightly increased = 4</td>
</tr>
<tr>
<td></td>
<td>Considerably increased = 5</td>
</tr>
<tr>
<td>Change in consumption of salt</td>
<td>Considerably decreased = 1</td>
</tr>
<tr>
<td></td>
<td>Slightly decreased = 2</td>
</tr>
<tr>
<td></td>
<td>Stayed the same = 3</td>
</tr>
<tr>
<td></td>
<td>Slightly increased = 4</td>
</tr>
<tr>
<td></td>
<td>Considerably increased = 5</td>
</tr>
<tr>
<td>Change in consumption of fat/oily food</td>
<td>Considerably decreased = 1</td>
</tr>
<tr>
<td></td>
<td>Slightly decreased = 2</td>
</tr>
<tr>
<td></td>
<td>Stayed the same = 3</td>
</tr>
<tr>
<td></td>
<td>Slightly increased = 4</td>
</tr>
<tr>
<td></td>
<td>Considerably increased = 5</td>
</tr>
<tr>
<td>Change in consumption of sweets</td>
<td>Considerably decreased = 1</td>
</tr>
<tr>
<td></td>
<td>Slightly decreased = 2</td>
</tr>
<tr>
<td></td>
<td>Stayed the same = 3</td>
</tr>
<tr>
<td></td>
<td>Slightly increased = 4</td>
</tr>
<tr>
<td></td>
<td>Considerably increased = 5</td>
</tr>
<tr>
<td>Change in consumption of caffeine</td>
<td>Considerably decreased = 1</td>
</tr>
<tr>
<td></td>
<td>Slightly decreased = 2</td>
</tr>
<tr>
<td></td>
<td>Stayed the same = 3</td>
</tr>
<tr>
<td></td>
<td>Slightly increased = 4</td>
</tr>
<tr>
<td></td>
<td>Considerably increased = 5</td>
</tr>
<tr>
<td>Change in appetite</td>
<td>Considerably decreased = 1</td>
</tr>
<tr>
<td></td>
<td>Slightly decreased = 2</td>
</tr>
<tr>
<td></td>
<td>Stayed the same = 3</td>
</tr>
<tr>
<td></td>
<td>Slightly increased = 4</td>
</tr>
<tr>
<td></td>
<td>Considerably increased = 5</td>
</tr>
<tr>
<td>Tendency to eat out</td>
<td>Considerably decreased = 1</td>
</tr>
<tr>
<td></td>
<td>Slightly decreased = 2</td>
</tr>
<tr>
<td></td>
<td>Stayed the same = 3</td>
</tr>
<tr>
<td></td>
<td>Slightly increased = 4</td>
</tr>
<tr>
<td></td>
<td>Considerably increased = 5</td>
</tr>
<tr>
<td>Tendency to prepare own food</td>
<td>Considerably decreased = 1</td>
</tr>
<tr>
<td></td>
<td>Slightly decreased = 2</td>
</tr>
<tr>
<td></td>
<td>Stayed the same = 3</td>
</tr>
<tr>
<td></td>
<td>Slightly increased = 4</td>
</tr>
<tr>
<td></td>
<td>Considerably increased = 5</td>
</tr>
<tr>
<td>Tendency to buy own groceries</td>
<td>Considerably decreased = 1</td>
</tr>
<tr>
<td></td>
<td>Slightly decreased = 2</td>
</tr>
<tr>
<td></td>
<td>Stayed the same = 3</td>
</tr>
<tr>
<td></td>
<td>Slightly increased = 4</td>
</tr>
<tr>
<td></td>
<td>Considerably increased = 5</td>
</tr>
<tr>
<td>Reading and using information on food labels</td>
<td>Yes = 1; No = 0</td>
</tr>
<tr>
<td>Counting calorie content of food consumed</td>
<td>Yes = 1; No = 0</td>
</tr>
</tbody>
</table>
The Effectiveness of Weight Control through Weight Watch Programs

Consider the following model aimed at predicting the change in the BMI for participants in this study:

\[
Y_i = 1 \text{ if } Y_i^* = X_i \beta + \varepsilon_i \geq 0 \\
Y_i = 0 \text{ if } Y_i^* = X_i \beta + \varepsilon_i < 0
\]

where \( Y_i \) is an observed dummy variable which takes the values of 1 when the participant’s BMI has increased at the end of the experiment period and 0 otherwise, \( Y_i^* \) is the latent variable (unobserved critical threshold), \( X_i \) is a vector of regressors, \( \beta \) is a vector of parameters, and \( \varepsilon_i \) is the error term.

Assuming that \( \varepsilon_i \sim N(0, \sigma^2) \), \( \varepsilon_i / \sigma \) is distributed as standard normal (mean zero and unit variance). Equation (1) can therefore be estimated using a probit model. The parameter estimates are obtained using the Maximum Likelihood Method (Maddala 1983).

Literature review

The choice of independent variables was based on the review of literature related to the topic of the research. Most studies agree that lifestyle has tremendous influence on BMI. The weight of individuals depends on the type, level, and frequency of physical activity and food choices, including amounts of sweets, fatty foods and meat. The frequency of “eating outside of home”, the number of hours sleeping in a day, level of emotional stress, and demographics also play an important role.

Physical activity is known to increase the body metabolism and therefore energy expenditure, which translates into reduction in the body weight. Research concluded that 45 to 60 minutes of daily exercise can help prevent normal-weight individuals from becoming overweight. Studies report that almost 60% of adults never engage in any kind of outside-the-work demands, physical activity lasting 10 minutes or more per week (Brownson et al. 2005).

The influence of gender on the dietary trends and eating habits was studied in the group of college students. A higher percentage of women than men had tried a low-fat diet and a low-carbohydrate diet. Significantly higher percentages of women than men agreed that they had too much sugar in their diets and that it is important to limit carbohydrate consumption and amount of fat consumption to lose weight. (Davy et al. 2006)

Cultural norms and socio-economic status also influence food preferences and dietary choices and, therefore, influence the BMI of individuals. According to the Mokdad, obesity in the United States is more prevalent in the Southern States (Mokdad et al. 2001).

The prevalence of obesity among African Americans is 30%, compared to 25% in Hispanics and 18% in whites. Another study that assessed BMI among urban low socio-economic status (SES) African-American adolescents concluded that students’ behaviors, school, and family environments may increase overweight risk among this population (Youfa et al. 2007).

Recent studies suggest that short sleep duration is associated with obesity. Truck drivers, for example, work irregular shifts and their work schedule is associated with short-sleep duration. A study of this group has shown an association of short-sleep duration with high levels of blood glucose and cholesterol levels, which contribute to obesity (Moreno et al. 2006). Kohatsu and colleagues have suggested existence of a link between short sleep duration and BMI in a rural population in Southeast Iowa (Kohatsu et al. 2006). Another study reports nationally representative data on the sleep habits of American children age 3-18 years. This study emphasizes the importance of sleep in children’s physical health and suggests that sleep is important factor in understanding childhood weight problems (Snell et al. 2007).

Stress levels of the individuals can affect their BMI. In general, emotional stress is known to trigger overeating—consuming large amounts of food within a short period of time (Vanderlinden et al. 2004). The excess calories become converted into fat and are stored in the adipose tissue.

Preexisting health conditions can also affect the weight of individuals. Diabetes mellitus is a disorder characterized by insulin resistance and, as a result, elevated levels of glucose in the blood. Ninety five percent of people with diabetes have type 2 diabetes. Obesity, especially central obesity and a sedentary lifestyle (exercise fewer than three times per week) are risk factors associated with type 2 diabetes (Haas 2010). Eighty percent of individuals that are diagnosed with type 2 diabetes are overweight. Adults who are overweight are significantly more likely to develop type 2 diabetes than are individuals with BMI in normal range (Hu et al. 2001). Scientists estimate that 18 million Americans will have type 2 diabetes by the year 2020 (Green et al. 2003). In addition to overall obesity, the distribution of body fat is also a risk factor for type 2 diabetes. In many cases, type 2 diabetes is preventable. For people at risk for type 2 diabetes, weight management, regular exercise, and a healthy diet can reduce the risk (Gill and Cooper 2008). Even small changes can make a big difference. For example, losing as little as 10 to 15 pounds or taking a 30-minute walk daily have been shown to lower blood glucose...
and thus possibly prevent development of diabetes.

Metabolic syndrome is another condition that is associated with insulin resistance. Approximately 47 million adults in the United States (20%) have metabolic syndrome (Shaw et al. 2005). Risk factors associated with metabolic syndrome are the same as those associated with type 2 diabetes: obesity, poor eating habits, and lack of exercise.

High intakes of protein are often accompanied by high intakes of fat, saturated fat, and cholesterol. In addition, growing research shows that very high, chronic intakes of red meat (beef, pork, and lamb) or processed meats (bacon, sausage, hot dogs, ham, and cold cuts) are associated with increased risk for colorectal cancer (Chao et al. 2005). Nonmeat-eaters are generally thinner than meat eaters. Studies attribute this difference to a higher intake of dietary fiber and a lower intake of animal fat (Appleby et al. 1998). Another study compares BMI in four diet groups (meat-eaters, fish-eaters, vegetarians and vegans). Fish-eaters, vegetarians, and vegans especially had lower BMIs than meat-eaters. High protein and low fiber intakes were the factors associated with increasing BMI (Spencer et al. 2003). Consuming less meat and fat may lead to lower overall energy-containing nutrients intake, which in turn results in weight loss. Foods that are low in fat content can benefit health overall by lowering total and LDL cholesterol blood levels, increasing HDL cholesterol, and improving blood glucose regulation (Lovejoy JC et al 2003).

There are rising trends in adults eating away from home, portion sizes of food increasing, and consumption of energy dense food increasing (Enns et al 2003). While the amount of calories consumed is increasing, Americans are also becoming less physically active. According to the research, 37% of adults and 42% of children eat fast food daily (Brilfel and Johnson 2004). Many fast-food restaurants offer healthy food choices such as salads, but overall most fast meals remain high in fat, simple carbohydrates, and calories. One the studies reports that fast food is nutritionally adequate but exceeds the national recommendations for fat, sugar, and sodium (Anding et al. 2001).

Analysis of the data from the National Health Interview Survey (NHIS) and the National Health and Nutrition Examination Survey (NHANES) 1999-2000 that examined trends in frequency of consumption of commercially prepared meals, lead to believe that in 1999-2000 more Americans ate out, and ate out more frequently. This trend is associated with adverse nutritional consequences (Kant and Graubard 2004). Foods with large amounts of added sugars, such as soft drinks, cakes, cookies, and candy, often have no or very little nutritional value beyond the calories they contain. In recent years, the consumption of added sugars in the United States has increased. Thirty three percent of the sugars come from soft drinks alone. Overall, Americans consume 80 g of added sugar per day – for a total of 320 kcal (Guthrie and Morton 2000).

Alcohol is not considered a nutrient, because it does not supports growth and development, but it does contribute to the amount of calories consumed by providing 7 kcal per gram. Excessive alcohol consumption can contribute to an increase in Body Mass Index (Suter and Tremblay 2005).

Results and Discussion

Results of the linear probability estimation are summarized in Table 3 below.

Demographic characteristics seem to play an important role in weight and BMI reduction. First, the age of participants positively associates with increases in BMI. This result suggests that the older one gets, the harder it is to decrease one’s BMI. Older people have a relatively slower metabolism, which translates into less energy expenses. Also, adults aged 35 or above exercise relatively less than their younger counterparts. Results also suggest a significant gender difference. Unlike females, males in this study are positively associated with changes in BMI. Males are usually known to be more athletic and more engaged in physical exercise than females. This helps men expend more energy. Our results also show a differential response by race. Unlike Whites, the Body Mass Index of Blacks in our study has shown a significant increase.

Exercising is generally known to boost metabolism, burn energy, and, therefore, reduce the BMI. Also, exercising increases the amount of endorphins that are released in the blood, which decreases appetite, supposedly leading to a reduction in BMI. However, at this time our study does not confirm that.

Food choices have shown some influence on the BMI of participants. An increase in vegetable intake leads to the decrease in BMI, as expected. Vegetables are composed of soluble fiber and water. They provide satiety and feeling of “being full” with less calorie intake.

Furthermore, we found a direct link between BMI and the amount of red meat consumed. It is common to
The Effectiveness of Weight Control through Weight Watch Programs

Table 3: Linear probability estimation results

<table>
<thead>
<tr>
<th>Independent variable</th>
<th>Coefficient estimate</th>
<th>Standard error</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-15.199*</td>
<td>0.221221D+07</td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>0.681***</td>
<td>32635.6751</td>
<td>36.94</td>
</tr>
<tr>
<td>Male</td>
<td>-21.495***</td>
<td>0.165418D+07</td>
<td>0.23</td>
</tr>
<tr>
<td>Black</td>
<td>27.335***</td>
<td>0.111167D+07</td>
<td>0.28</td>
</tr>
<tr>
<td>Exercise time</td>
<td>0.214</td>
<td>10237.1231</td>
<td>28.57</td>
</tr>
<tr>
<td>Vegetables consumption</td>
<td>-5.784**</td>
<td>978834.033</td>
<td>0.83</td>
</tr>
<tr>
<td>Red meat consumption</td>
<td>22.5503867</td>
<td>981575.785</td>
<td>-0.43</td>
</tr>
<tr>
<td>Soda consumption</td>
<td>-7.553*</td>
<td>437213.331</td>
<td>-1.11</td>
</tr>
<tr>
<td>Alcohol consumption</td>
<td>-2.615***</td>
<td>609379.013</td>
<td>-0.48</td>
</tr>
<tr>
<td>Fruits consumption</td>
<td>0.401*</td>
<td>965631.124</td>
<td>0.88</td>
</tr>
<tr>
<td>Milk consumption</td>
<td>12.515***</td>
<td>788328.539</td>
<td>0.11</td>
</tr>
<tr>
<td>Fat food consumption</td>
<td>17.615**</td>
<td>734663.589</td>
<td>-0.94</td>
</tr>
<tr>
<td>Salt consumption</td>
<td>4.197*</td>
<td>357909.793</td>
<td>-0.51</td>
</tr>
<tr>
<td>Eating out</td>
<td>-13.815**</td>
<td>775977.234</td>
<td>-0.80</td>
</tr>
<tr>
<td>Calories checking</td>
<td>-2.085*</td>
<td>597727.269</td>
<td>0.60</td>
</tr>
<tr>
<td>Sleep time</td>
<td>-3.735*</td>
<td>303146.143</td>
<td>6.44</td>
</tr>
</tbody>
</table>

Log likelihood function: -0.1077027E-11
Restricted log likelihood: -19.95165
Chi squared: 39.90330

*, **, *** indicate that the estimated coefficient is statistically significant at 10%, 5%, and 1% respectively.

think that meat as “all protein”, while, in fact, a large portion of the composition of meat foods is fat. So, naturally, an increase in red meat consumption would lead to the increase in overall calories consumed and would contribute to the increase in BMI.

Increases in soda consumption were negatively associated with BMI. It could be the case that soda consumed was diet soda that does not contains added sugar. Then, increase in sugar-free soda consumption will lead to the decrease of the BMI. If regular soda was consumed, the expected relationship would be a direct relationship, because regular soda provides a lot of sugar and sodium, which would lead to the increase in BMI.

Alcohol consumption shows a negative association with the BMI. However, this result can be considered inconclusive. Alcohol is not a nutrient, but does contribute calories and, if consumed in excess, may lead to the increases in BMI.

Increases in fruit consumption showed a slight increase in BMI. This could be explained by the fact that fruits contain insoluble fiber and water as well as sugar. Increases in the amount of insoluble fiber and water will lead to the increase of the BMI. Our study also shows a direct relationship between milk consumption and increases in BMI. Milk is essentially composed of water, carbohydrates, and fat. So, increases in milk consumption will contribute to calories consumed and lead to an increase in the BMI.

The BMI increases with increases in fat food intake and this is consistent with expectations. Fat provides twice the calories compared to the carbohydrates and protein. Also, fatty foods may contain a considerable amount of salt, which leads to the water retention and is translated to an increase of the BMI.

Increase in salt intake demonstrated increases in BMI. Increases in BMI in this case could be attributed to the increase in overall body water retention.

The impact of eating away from home on BMI was inconclusive. It is generally expected that eating outside of the home will lead to increases of the BMI, because it is difficult to know how many calories are consumed during meals outside of the home. Also, it is easier to overeat because of the food availability. Healthy meals prepared at home are expected to demonstrate a decrease in the BMI. Investigators are hoping to confirm this expectation in future studies.

Checking the caloric content of various food items while shopping for groceries can help monitor calorie intake and weight and lead to reductions in BMI. Our research was able to confirm that recommendation.
Results show an inverse relationship between number of hours sleeping and BMI. Less sleep translates into having less energy available for the next day, which leads to the increases in appetite next day in an attempt to compensate for lost energy and, consequently, leads to the increase in BMI.

Concluding comments

This study confirms the influence of demographics, dietary habits, and other lifestyle choices on BMI of individuals. Our analysis of the collected data documents the idea that individuals can successfully manage their body weight by adopting healthier lifestyles. Educational programs aimed at controlling weight can therefore be successfully implemented through weight management programs.

References


The Effectiveness of Weight Control through Weight Watch Programs


Search for the Next “Silver Bullet”: A Review of Literature

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Abstract

We present a review on the application of silver-containing compounds that have been incorporated in the surfaces of a large variety of medical devices including vascular, urinary, and peritoneal catheters, endotracheal tubes, sutures, and fracture fixation devices, as well as other materials such as plastics in kitchen appliances and fabrics. We found renewed and rising interest in silver-containing materials due to their antimicrobial, including antiviral and antifungal, properties, their good toxicology and environmental record. Silver-containing compounds could be used against bacterial strains that are known to be resistant to antibiotics. More research is necessary to determine safe levels and particle-size of silver for use in humans.

Keywords: silver; antimicrobial, antibacterial.

Introduction

The search for new antimicrobial agents is an ongoing process. The rising numbers of antibiotic resistant bacterial strains (Rosenblatt-Farrell 2009), immunodeficiency, and an increase in chronic diseases such as diabetes that decrease the natural healing capability of the organism drive the search.

Silver has a long history of use by humans. In ancient times it was used to purify and store water. Alexander the Great (335 BC) drank water from silver-containing vessels (Russel et al. 1994, White 2002). Silver was used aboard the Apollo, the MIR space station, and NASA space shuttles for water purification (Conrand et al. 1999). In 1800, 2% silver nitrate was used for treatment of ophthalmia neonatorum in newborns (Klasen 2000). Since the 1960’s, silver sulfadiazine has been used as a topical antibacterial (Fox 1968). The emergence of resistant strains of bacteria, such as MRSA, provoked the search for new antimicrobials. There is an increasing interest in silver-containing materials due to their antimicrobial properties in applications such as pharmacology, medicine, the food industry and the healthcare environment (Petica et al. 2008).

Advances have been made in the last decade in medical grade silver technology, from the synthesis of safer and bioavailable silver compounds to new delivery techniques and new environmentally friendly “green” silver containing disinfectants.

The purpose of this literature review is to discuss the use of silver-containing compounds in medicine and beyond.

Why does silver work?

Russel et al (1994) found that silver binds to bacterial DNA and affects cell replication. By interfering with replication, silver ions reduce the number of the bacteria, eventually killing the entire population (Russel et al. 1994).

According to the Kong and Jang (2008), there are several possible explanations of bactericidal properties of silver: 1) silver ions inhibit ATP synthesis via binding to the enzyme associated with ATP generation in the cell, 2) silver ions enter the cell, bind to its DNA, leading to DNA denaturation, 3) silver ions block the respiratory chain in the cytochrome oxidase and NADH-succinate dehydrogenase region, inhibiting ATP generation by the microorganism.

Petica et al (2008) believe that the mechanism of the antibacterial effects of the silver ions (Ag⁺) involves their absorption and accumulation by bacterial cells and shrinkage of the cytoplasmic membrane and its detachment from the cell wall. Due to the infiltration of the cell by Ag⁺ ions, DNA molecules become condensed and incapable of replication.

It has been reported that the mode of action of silver nanoparticles is similar to that of silver ions. However, the effective bactericidal concentration of silver nanoparticles is at a nanomolar level as compared to a micromolar level for silver ions (Kong and Jang 2007).

Current Applications

Use of medical devices, such as central venous or urinary catheters, is associated with infection risks due
to the inevitable colonization of the catheter surface by bacteria. With a goal to reduce infection, silver based molecules of different size and concentrations have been incorporated into the surfaces of a large variety of medical devices including bladder catheters, central venous catheters and peritoneal catheters.

**Catheters**

A study by Jansen and colleagues (1994) evaluated the *in vitro* biocompatibility and the antimicrobial activity of silver-coated polyurethane catheters. The catheters were designed to be used as an antimicrobial material and to prevent the bacterial colonization associated with use of a catheter. The antimicrobial activity of the catheters was tested using *Staphylococcus epidermidis*, *Escherichia coli* and *Pseudomonas aeruginosa*. Catheters coated with silver demonstrated antimicrobial capability and performed well in cell toxicity, blood compatibility, and acute toxicity tests in mice. For all test strains, a reduction in the number of adherent cells to the silver-coated catheters was observed, which was more pronounced after an adherence time of 24 h. In a case of *S. epidermidis* (10⁶ cfu/ml) % reduction of adherence in 3 h was 82.7% and 90% in 24 h, 90% in 3 h; 83.7% in 24 h for *E. coli* and 99.9 % in 3 and 24 h for *P. aeruginosa*. With an inoculum of 10⁵ cfu/ml, *S. epidermidis* demonstrated 94.6 % reduction of adherence in 3 h and 80.0 in 24 h, *E. coli* - 93.3% in 3 h and 99.1 % in 24 h, and *P. aeruginosa* – 99.9% in 3 h and 24 h (Jansen et al. 1994).

According to research from the University of Michigan Health System, 5% of hospitalized patients that undergo urinary catheterization develop bacteriuria. Proper management of the drainage system, including use of the antimicrobial agents and rigorous cleansing, was emphasized, but seem to have only a small benefit. Saint and Lipsky (1999) analyzing results of 8 randomized trials involved silver-coated urinary catheters found, that silver alloy catheters were significantly better in prevention of bacterial infections than noncoated control catheters and it would be reasonable to consider using silver alloy catheters in hospitalized patients (Saint and Lipsky 1999).

Johnson and associates (2006) have also concluded that “antimicrobial urinary catheters can prevent bacteriuria in hospitalized patients”, but the effect depends on the characteristics of the antimicrobial coating, such as the size of the silver particles (Johnson et al. 2006).

Loertzer and colleagues (2006) found evidence that the use of catheters coated with silver reduced the risk of infection in kidney transplant recipients. There is an increased risk of microbial infection in transplant patients due to immunosuppression therapy (Zand 2005). The main cause of the catheter-related infections is microbial colonization of the central venous catheters. Catheters were analyzed microbiologically. Catheters coated with silver demonstrated a significant reduction in associated infections of the blood stream, as well as increased protection against bacteria and fungi during the entire time of catheterization (Loertzer et al. 2006).

**Endotracheal tubes (ETTs).**

Endotracheal tubes are often used in the management of a patient’s airway. Bacterial biofilms may form on the surface of the endotracheal tubes in and around the place of the insertion and may increase risk of the pneumonia being developed by the patient.

Berra et al (2008) developed and tested ETTs coated with silver sulfadiazine (SSD). In the in- vitro study SSD-ETTs demonstrated bactericidal properties against *P. aeruginosa*, preventing biofilm formation on ETT lumen in 6, 24 and 72 h, whereas standard ETT (St-ETT) showed heavy *P.aeruginosa* growth and biofilm formation (p<0.01). In 24-h study of young female Dorset sheep, 4 sheep received SDD-ETT and showed no bacterial growth in ETT, while heavy colonization was found in sheep received St-ETT (p<0.01) (Berra et al. 2008).

**Silver-coated megaprosthesis**

Despite the use of antibiotic prophylaxis, infection rates associated with implantation of prostheses remain high. Gosheger et al (2004) evaluated the antimicrobial efficacy and side effects of the silver coated megaprosthesis. 15 rabbits received titanium endoprostheses and 15 – silver coated one. Both groups were infected with *Staphylococcus aureus* (Strain number A 22616-5) isolated from bone specimen of a 34 years-old female with osteomyelitis. After 90 days of observation, group of rabbits with silver coated endoprosthesis demonstrated significantly lower inflammation sigs (p<0.005) including C-reactive-protein and neutrophilic leukocytes measurements in comparison with the group with titanium endoprosthesis. Infection rates were also significantly lower in the group with silver endoprosthesis (7% versus 47% ). The silver concentration in the blood and organs of the rabbits were elevated (mean 1.883 and 0.798-86.002 ppb respectively), but did not cause pathological changes in the organs including brain,
heart, kidney and reproductive organs (Gosheger et al. 2004).

**Dental care**

Scientists are in agreement that dental caries caused by *Streptococcus mutans* is a worldwide, public health concern, especially in patients whose immune system has been compromised.

Hernandez-Sierra et al (2008) used nanoparticles of silver, zinc oxide, and gold of an average size of 25 nm, 125 nm and 80 nm respectively to demonstrated bacteriostatic and bactericidal effects on *S. mutans*. Findings showed that nanoparticles of silver, as compared with those of gold and zinc oxide, required a lower concentration (MIC on average 4.86±2.71µg/mL) to inhibit development of the *S. mutans* strains compared to the zinc oxide (MIC on average 500±306.18µg/mL) and gold (MIC on average 197 µg/mL) leading to consideration that silver particles may be most effective for controlling *S. mutans* and therefore caries (Hernandez-Sierra et al. 2008).

Three sizes of silver nanoparticles were used to find minimum inhibitory concentration (MIC) for *Streptococcus mutans* in the study by Espinosa-Cristobal and associates (2009). Nanoparticles with the lowest MIC was 8.4 nm in diameter, followed by 16.1 and 98 nm, suggesting that antibacterial property of silver nanoparticles possibly depend on the size of the particles (Espinosa-Cristobal et al. 2009).

**Eye care**

Antimicrobial medications that are traditionally used on the ocular surface are effective, but they are rapidly cleared through the tear ducts, reducing contact time and drug effectiveness.

Contact lenses containing silver nanoparticles as an antimicrobial measure have been studied. Santoro et al. (2007) investigated silver nanoparticles as a source of silver ions against contact lens-associated bacterium, *Pseudomonas aeruginosa* strain PA01. BBL™ Prompt™ tube containing 1.5 ×10⁸ CFU/ml *P. aeruginosa* was inoculated to 1 ×10⁶ CFU/ml in Erlenmeyer flasks containing 20 ml media with silver nanoparticles. Also, solutions of 20 ml media containing various concentrations (2, 4, 6, 10 µM) of control silver nitrate were inoculated to 1 ×10⁵ CFU/ml of bacteria. Flasks were incubated overnight at 37 °C while shaking at 200 rpm. Minimal bactericidal effects were observed for several nanoparticles suspensions (with maximum of 2.6 µM silver ion concentration), which believed to be due to that silver particles themselves at this concentration and size ranging from 20 to 60 nm are not microcidal under conditions tested and substantial increase in silver particle loading in the lens in the future experiments will allow to produce desirable bactericidal effect (Santoro et al. 2007).

**Silver-antibiotic combination**

Shahverdi et al (2007) demonstrated that combining penicillin G, amoxicillin, erythromycin, clindamycin, and vancomycin with silver nanoparticles leads to an increase in antibacterial activity of the antibiotics against *Staphylococcus aureus* and *Escherichia coli*. This finding suggests that combining antibiotics with silver nanoparticles increases antibacterial properties of antibiotics (Shahverdi et al. 2007). In addition, according to Patil and coworkers, chloramphenicol loaded with nanoparticles showed substantially enhanced activity against *Salmonella typhi* (Patil et al. 2009).

**Silver and wound care**

Chronic wounds are more likely to be colonized by normal bacterial microflora such as *Staphylococcus aureus* and *Streptococcus epidermidis* that easily become cause of opportunistic infection. Silver containing material could be used to reduce risks and duration of infections associated with opportunistic microorganisms.

Castellano et al (2007) reported using eight commercially available silver-containing dressings Acticoat® 7, Acticoat® Moisture Control, Acticoat® Absorbent, Silvercel™, Aquacel®, Coutreet™, Urgotol®, SSD, and Actisorb®. Dressings were tested in vitro for antimicrobial effectiveness against *Escherichia coli* (ATCC 25922), *Pseudomonas aeruginosa* (ATCC 27853), *Streptococcus faecalis* (ATCC 29212) and *Staphylococcus aureus* (ATCC 29213). Zone of bacterial inhibition was measured after 24, 48, and 72 hours. Silver-containing dressings were also compared to efficacy of antimicrobial creams and topical silver containing antimicrobial gel Silvasorb. Results of this study suggested that all silver dressings displayed antimicrobial activity; however, their bactericidal and bacetriostatic properties were secondary to commonly used topical antimicrobial agents such as Sulfamylor® and Gentamicin Sulfate Cream 0.1%.

Ballard and McGregor (2002) described using silver hydropolymer dressing Avance and Avance A for open exuding chronic wounds. In the clinical trials on three patients over a 4-week period Avance demonstrated many of the characteristics of the ideal dressing. It had ability to absorb exudate, had
Search for the Next “Silver Bullet”: A Review of Literature

Antimicrobial effect and was easy to use. Silver-containing hydrocol polymer dressing Avance not only facilitated healing of the wound, but also enhanced quality of life by reducing pain.

Stephen-Haynes and Toner (2007) emphasized importance of accurate wound assessment and holistic choice of the silver-containing material for facilitation of wound healing and wound healing success. Multilaminate high density polyethylene dressing containing nano-crystalline silver Acticoat/Acticoat 7 demonstrated effectiveness in healing of pressure ulcers, venous ulcers and diabetic ulcers. Actisorb Silver 220 containing hydrocolloid fibers with silver was effective against heavy odorous and infected chronic wounds and ulcers. Hydroalginate with silver Silvercel was effective against MRSA.

Benbow (2005) described improvement in wound healing using SILVERHEALING wound pad containing metallic silver under a polyethylene net from which silver ions are released when it comes into contact with exudates. Reportedly, the effect of this material that has been tested against Staphylococcus aureus, Escherichia coli, Pseudomonas aeruginosa and Candida albicans is immediate, inhibitive, and hypoallergenic.

Jain et al (2009) concluded that silver nanoparticles could have successful therapeutic use as a part of the antimicrobial gel for topical use. A standard antimicrobial sensitivity tests carried out in Muller-Hinton agar plates were used to evaluate the antimicrobial activity of the silver nanoparticles containing gel against bacterial cultures of Escherichia coli (ATCC 117), Pseudomonas aeruginosa (ATCC 9027), Staphylococcus aureus (ATCC 6538), and Streptococcus epidermidis (ATCC 12228). Gram-negative bacteria were killed more effectively (3 log decrease in 5-9 h) than Gram-positive bacteria (3 log decrease in 12 h). Gel also exhibited good antifungal activity (50% inhibition at 75 μg/mL with antifungal index 55.5% against Aspergillus niger and MIC of 25 μg/mL against Candida albicans). Acute dermal toxicity studies on gel formulation (S-gel) in Sprague-Dawley rats showed complete safety for topical application.

Silver in tumors treatment

Maaskant et al (2009) examined the effectiveness of chlorhexidine-silver sulfadiazine impregnated central venous catheters (CVCs) in patients that received high-dose chemotherapy followed by peripheral stem cell transplantation. Patients were treated for different diagnoses including breast cancer, Non-Hodgkin lymphoma, testicular cancer, Hodgkin’s disease, Kahler’s diseases, Ewing sarcoma, and other cancers. Study evaluated 139 patients of whom 69 were provided with impregnated CVCs and 70 patients with non-impregnated CVCs. The median number of day a CVC has been used was 16 days in impregnated group and 18 days in non-impregnated group. Less catheter colonization was found in the patients with chlorhexidine-silver sulfadiazine CVCs (RR 0.63, 95% CI 0.41-0.96; P=0.03). These results were clinically significant, because colonized CVCs could be a source of systemic infections. Catheter-related blood stream infections were also less frequent, but the results did not meet statistical significance (RR 0.15, 95% CI 0.02-1.15; P=0.06).

Silver nanoparticles have demonstrated inhibition of the formation of new blood vessels (angiogenesis) in mice with tumors, possibly due to inactivation of PI3K signaling pathways. Because angiogenesis is an important part of normal and pathological growth, this research is a significant finding for future treatment of the malignant, ocular, and inflammatory diseases (Gurunathan et al. 2009).

Silver in fabrics

Use of silver-containing nanoparticles in fabrics was studied by several scientists. The goal of the study was to examine the antimicrobial activity in cotton fabrics loaded with colloidal silver nanoparticles. Also studied were the antimicrobial affects of silver deposited onto fabric surfaces against Escherichia coli, Staphylococcus aureus, and the fungus Candida albicans. Cotton fabrics loaded with silver nanoparticles exhibited good antimicrobial activity (Ilic et al. 2009).

Textile fibers and fabrics have a wide variety of biomedical applications. According to Russo and Maffezzoli (2009), there are not too many fabrics with a good degree of biocompatibility, resistance to autoclaving, and antibacterial properties. To fill this void, the silver-coated fibers were developed and demonstrated good coating stability together with antimicrobial efficacy (Russo and Maffezzoli 2009). Hipler et al (2005) presented a study that was intended to test whether silver-covered seaweed-based fibers Sea Cell® Active exert antibacterial and antifungal properties. Colonies of pure culture of Staphylococcus aureus (ATCC 22926) and Escherichia coli (ATCC 35218) were inoculated in 5 mL Mueller-Hinton broth and incubated at 37 °C until the turbidity of suspension was equal to that of 0.5 McFarland. Sea Cell® Active was then placed in the center of Muller-
Hinton agar plates that had been inoculated with test bacteria and incubated at 37°C for 24 h. Fibers demonstrated excellent antibacterial properties with highest activity with Sea Cell® Active fibers with 100% of the active silver load. Sea Cell® Active also demonstrated reduction of the cell proliferation of the Candida species (DSM 11225, ATCC 1169, ATCC 6258) down to 10-20% compared with control.

**Silver and MRSA**

An article in *Medical Technology and Devices Week* reported on the potential use of the silver in preventing the spread of bacterial strains, including methicillin-resistant *Staphylococcus aureus* (MRSA). It described the capability of silver to kill strains of bacteria that were resistant to current treatments using antibiotics (Ford et al 2007).

O’Hanlon and Enright (2008) evaluated the antistaphylococcal activity of commercially available silver containing textile treatment Clineweave® (CW). Testing included 49 meticillin-resistant genetically diverse *Staphylococcus aureus* strains (MRSA) Antimicrobial activity of CW-treated polyester was compared to three other commercially available silver-containing antimicrobial fabrics. In this study only CW-treated fabric demonstrated any significant antibacterial activity and reduction of bacterial numbers within 1 h. Time-kill study of liquid CW in culture showed 2 log reduction of MRSA within 30 min and 3 log reduction of MRSA within 240 min. Silver containing textile Clineweave® proved to be biocidal and useful for reduction of MRSA burden.

**Other areas of silver use**

Silver-containing compounds have reportedly been used in material that is used to make binders, markers and staplers. In Europe antibacterial silver-based polymers include hospital equipment, medical packaging, and door handles. Silver based antimicrobial Makrolon polycarbonate is used in medical devices like intravenous (IV) systems, urological devices, and housing for diagnostic and hospital equipment (Markarian 2009).

Samsung Electronics manufactures new appliances that use a silver-based antibacterial material termed “silver nano health systems” (SNHS). Samsung washing machines contain nano silver particles coating, refrigerators that use silver trays and that are coated with silver water-filters, tubes, and air conditioner surfaces. LG Electronics produces refrigerators with a silver-containing coating in the internal food storage compartment.

Jo and colleagues examined the use of silver in the control of plant diseases caused by pathogenic fungi *Bipolaris Sorokiniana* and *Magnaporthe grisea*. Results indicated that silver ions and nanoparticles affected disease progress and spore formation in plant pathogenic fungi, reducing the progress of the disease (Jo et al. 2009).

**What about toxicity?**

In view of silver’s potential toxicity, extensive and in depth research is needed.

Despite the opinion that there is no silver accumulation in tissue after topical application, autopsy study of two patients treated for 1 and 6 month respectively for burns with 0.5% AgNO₃, revealed significant silver deposition in multiple organs. Autopsy study on a burned child treated with silver sulfadiazine cream (AgSD) for 3 months showed silver deposition in liver and kidney with concentration of the silver in liver tissue 1600 times that of normal liver specimen (Fuller 2009).

Coombs et al (1992) in a study of 22 patients with burns treated with AgSD demonstrated rise in serum silver levels up to 20 times the normal level within 6 hours after the initial application. Thus, silver deposition in the tissue could occur whenever serum silver levels rises and remains above normal.

The most common condition described in the literature associated with prolong silver exposure is argyria, which characterized by a blue-gray discoloration of the skin and total silver concentration in the blood up to 4-6 g (Lee and Lee 1994, Lansdown 2002, Gosheger et al. 2004).

The latest technologies used for production of silver-containing compounds appear to be safe and effective (Lansdown 2002).

**Conclusions**

Silver has been used for centuries in the form of silver nitrate, silver sulfadiazine and metallic silver. Its use has somewhat declined because of the development and increased use of antibiotics. Today, new technologies are bringing silver back in the form of nanoparticles with potential antimicrobial effects.

The results of many studies have demonstrated that silver nanoparticles inhibit the growth of bacteria including *Staphylococcus aureus*, *Streptococcus epidermidis*, *Enterococcus*, *Pseudomonas aeruginosa*, *Klebsiella pneumonia*, *Escherichia coli* and fungi such as *Candida albicans*. Studies suggest that silver nanoparticles can be used as effective microbial growth
inhibitors, making silver applicable to diverse medical devices and antimicrobial control systems. Despite promising in vitro results, more research is needed to determine the concentration and size of silver particles that does not cause toxic silver levels in serum and/or damage to human organs, but that still provide bacteriostatic and bactericidal effect in humans.

Literature Cited


Stand conditions immediately following a restoration harvest in an old-growth pine-hardwood remnant

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Abstract

Portions of the Levi Wilcoxon Demonstration Forest (LWDF), a privately owned parcel of old-growth pine and hardwoods in Ashley County, Arkansas, were recently treated to restore conditions similar to some historic accounts of the virgin forest. Following a hardwood-only cut, a post-harvest inventory showed that the number of tree species in the sample area declined from 24 in 2006 (the most recent pre-harvest inventory) to 12 in 2009. Loblolly (Pinus taeda L.) and shortleaf (Pinus echinata Mill.) pine now comprise 59.2% of the remaining live trees, up from 16.2% in 2006. Between 2006 and 2009, basal area dropped from 28.2 to 16.4 m²/ha and stem density declined from 349.2 to 72.4 stems/ha, respectively. Total live biomass also fell from 224.8 Mg/ha in 2006 to 130.1 Mg/ha in 2009. While most of the pines in the LWDF are between 100 and 200 years old, ring counts on 102 randomly selected hardwood stumps yielded only one greater than 100 years old. Two-thirds of these hardwoods were less than 70 years old, having originated after the stand was set aside by the Crossett Lumber Company. Historical documentation and recent research suggest that the LWDF is now more similar to presettlement pine-dominated forests of southern Arkansas, which generally had lower stocking and fewer hardwoods.

Introduction

Ecosystem restoration has become an emphasis for public land managers (e.g., Bosworth and Brown 2007), but has been far less important for private landowners whose primary focus is timber production, agriculture, or other commodity-based objectives. However, increasing numbers of these owners are engaging in at least some level of restoration activity on their properties. As an example from the southeastern United States, large-scale efforts to restore bottomland hardwood forests on marginal or abandoned agricultural lands have been embraced by many ownerships, including farming and timber interests (e.g., Newling 1990, King and Keeland 1999, Stanturf et al. 2000). There are also significant efforts underway to restore fire-dependent longleaf pine (Pinus palustris Mill.) ecosystems on private lands in this region (e.g., Masters et al. 2003, Stanturf et al. 2004). Fewer efforts have been made in less high-profile ecosystems, but this is likely to change as interest grows in alternatives to production forestry.

Unlike bottomland hardwood or longleaf pine forests, wherein the primary challenge is to return the desired tree species to a position of canopy dominance, the relative abundance of loblolly (Pinus taeda L.) and shortleaf (Pinus echinata Mill.) pine-dominated stands usually means that ecosystem restoration focuses on developing long-term sustainability. For example, it has long been recognized that in the absence of significant disturbances such as wildfire or silviculture, mesic pine-dominated forests will gradually succeed to hardwood-dominated stands (e.g., Chapman 1942, Quaterman and Keever 1962, Halls and Homesley 1966, Switzer et al. 1979, Shelton and Cain 1999).

The reintroduction of controlled burning is one of the more common land restoration approaches on public ownerships. Over time, with properly applied fire regimes, it is possible to encourage pine at the expense of hardwoods. Fire can also reduce litter and duff layers and consume large woody debris, both of which tend to accumulate under no-burn conditions. However, burning is less appealing to many industrial and private landowners, who rarely have the resources available to sustain this management strategy. Furthermore, there are a number of liability issues related to controlled burning (e.g., smoke obscuring nearby highways, causing traffic hazards; air quality impacts) that make landowners reluctant to use this approach.

Since the challenges of using fire and other natural processes to maintain desired stand conditions are considerable (e.g., Rideout et al. 2003), other human-mediated controls (e.g., cutting) may be required to sustain the restoration efforts (Bauhus et al. 2009). In
particular, to ensure the perpetuation of the pine component when partial cutting is used as the primary restoration tool (e.g., Blair and Brunett 1976, Bragg 2004a), additional treatments are probably necessary. For example, Outcalt and Brockway (2010) demonstrated that targeted selection of undesired overstory species, coupled with post-harvest herbicide application and controlled burning, was the most rapid means to achieve their restoration goals in longleaf pine forests. Fortunately, private landowners often face considerably fewer regulatory and operational hurdles for using chemical or mechanical understory control (rather than adaptations of natural events such as fire) in their restoration efforts.

In the fall of 2009, the Levi Wilcoxon Demonstration Forest (LWDF), a privately owned parcel of old-growth timber located about 6 km south of Hamburg in Ashley County, Arkansas, experienced the first stage of an effort to restore the stand to conditions more closely resembling the pine-dominated virgin forests of this region. According to the management staff of Plum Creek Timber Company (the landowner), their approach is to first harvest most mid- and overstory hardwoods (retaining virtually all of the pine) in areas outside of riparian management zones. This cutting is intended to be followed by treatments to control hardwood reproduction and sprouting. If possible, fire will be introduced to limit fuel loads and hopefully permit the establishment of historical understory conditions (i.e., more graminoids, forbs, and scattered pine reproduction). This paper evaluates the success of the initial phase (partial overstory removal) in achieving a stand structure more consistent with presettlement conditions.

Methods

Study area description

The LWDF is found in the South Central Arkansas Subsection (231Ea) of the National Hierarchical Framework of Ecological Units (McNab and Avers 1994). Though not yet described to the finest resolution of this hierarchical framework, phases of the nearby North Louisiana Clayey Hills Landtype Association defined by Van Kley and Turner (2009) provide reasonable approximations of the natural vegetative communities of the LWDF. These include Shortleaf Pine-Southern Red Oak/Callicarpa-Chasmanthium Loamy Dry-Mesic Uplands and Water Oak/Mitchella Loamy Mesic Stream Bottoms.

The gently rolling (<2% slopes) Calloway and Grenada silt loam soils (Glossic Fragiudalfs) that dominate the study site are seasonably wet and heavily forested, usually in a mixture of pine and hardwood (Gill et al. 1979). Annual precipitation averages about 140 cm, and there are 200 to 225 frost-free days (Gill et al. 1979). The LWDF has an abundance of low, circular, natural-origin “prairie” or “pimple” mounds, some of which exceed 1 m in height and 20 m in diameter.

The LWDF was originally owned by the Crossett Lumber Company, which reserved the stand as a “natural area” in 1939 (Anonymous 1948). Management of this stand change little over the years, even after the Crossett Lumber Company was acquired by Georgia-Pacific in the early 1960s. During this period, only occasional salvage of dead or dying pines was done on the LWDF (Bragg 2004b, 2006). Georgia-Pacific eventually transferred their lands to a new entity, The Timber Company, which was soon sold to Plum Creek Timber Company. Further descriptions of the environment and history of the LWDF can be found in previous papers (e.g., Bragg 2004b, 2006).

Restoration harvest treatments

Conventional timber management in this region usually involves the clearcutting, followed by intensive site preparation (e.g., ripping and bedding, then herbicide use and/or fertilization) and the planting of genetically improved loblolly pine seedlings. Because of the special status of the LWDF, the current landowner chose not to follow this industrial silvicultural regime, but rather decided to try to restore the stand to a semblance of the pine-dominated presettlement forests of the region. Hence, most hardwoods, except those along riparian management zones, were harvested.

Because the landowner intends to reintroduce controlled burning to this stand and does not want accumulations of logging slash to lead to excessively hot fires and fire-related mortality in the pine overstory, most of the tops and branches of cut trees were also hauled to the landing and chipped for fuel at a local mill. The net result of these treatments was to produce an open, pine-dominated stand with a sparse understory and considerable exposure of mineral soil (Figure 1).
Figure 1. Pre- (a) and post-restoration (b) views of LWDF stand conditions, taken from different vantage points.
Plot establishment and sampling

The original set of twenty-four 0.1-ha study plots had been established by the author on the LWDF in the summer of 2000 and remeasured in 2006 (Bragg 2004b, 2006). The logging of this restoration began in August of 2009 and has destroyed most of these original plots. Hence, a new set of sample plots were placed in the same general area of the LWDF. Three transects, running parallel to Highway 425 and spaced 40 m apart, were established just southwest of the parking area along the highway and extend northeasterly to the first major stream drainage. Along each transect, six to eight 0.1-ha circular plots were established at staggered 80-m intervals to ensure no overlap between these new plots.

All live trees with diameter at breast height (DBH) of at least 9.1 cm were included in the 2009 inventory, with their species and DBH (to the nearest 0.1 cm) recorded. Measures of stand density (basal area, in \( \text{m}^2/\text{ha} \) and frequency, in stems/ha) were determined using the tallies of the 21 overstory plots. Within each overstory plot, 5 stumps of all species created by the restoration harvest were selected to approximate tree age. These stumps were a minimum of 15 cm in diameter, and were required to be intact (not excessively damaged by the logging) and visible to the pith (no missing rings due to decay). To randomize their selection, the first eligible stump encountered in each of 4 quadrats (NE, SE, SW, and NW) while traveling in a clockwise direction was chosen regardless of the distance from plot center (so long as the stump was within the plot). A fifth stump, the one closest to plot center that had not yet been sampled in any quadrat, was then selected from the remaining uncounted eligible stumps. If possible, species of the stumps were identified, and rings were counted in situ (no cross-dating was performed, so these are only approximate tree ages). Of the 105 ring-counted stumps, 102 were used to describe hardwood overstory age (in 3 quadrats, the only stumps were a few small pines cut during the restoration harvest). Pine ring count data for this stand can be found in Bragg (2004b, 2006).

Within each overstory plot, a 1-m² sampling frame was placed halfway along the radii of the plot following the 4 cardinal directions. This sampling frame delineated the search area for the immediate post-harvest woody plant understory. Tree reproduction, shrubs, and lianas were identified to species or taxonomic group and placed into one of six size classes: A (stems 15-74 cm tall); B (stems 75-136 cm tall); C (stems ≥ 137 cm tall but < 1.5 cm at DBH); 1 (stems 1.5-3.8 cm DBH); 2 (stems 3.9-6.3 cm DBH); and 3 (stems 6.4-9.0 cm DBH). The 1-m² sampling frames also defined the area used to estimate percent ground coverage of a number of different substrates, including mineral soil, live vegetation, large woody debris, litter and duff, and water. This assessment was made just prior to leaf drop in the fall of 2009. Since it was not possible to sample preharvest ground cover conditions for comparison, three transects, each containing twelve 1-m² sample plots were placed in March of 2010 in adjacent, unharvested portions of the LWDF with the same overstory as the treated area (the delay was due to circumstances beyond our control). With the exception of the hardwood ring counts and ground cover estimates, each of these measurements were compared to samples collected during the last inventory of the LWDF in 2006 (Bragg 2006).

Live tree biomass determination

Total live tree biomass was calculated using DBH as the main predictor. Jenkins et al. (2003) developed the following general equation for aboveground live tree biomass (\( LTB_{AG} \)) for each of these species groups based on published allometric relationships:

\[
LTB_{AG} = e^{\beta_0 + \beta_1 \ln(DBH)}
\]

(1)

where \( \beta_0 \) and \( \beta_1 \) are species group parameters. Belowground live tree biomass (\( LTB_{BG} \)) is treated as a near-linear relation with \( LTB_{AG} \) (Enquist and Niklas 2002):

\[
LTB_{BG} = 3.88(LTB_{AG})^{1.02}
\]

(2)

Because \( LTB_{AG} \) is an exponential function of DBH, \( LTB_{BG} \) also behaves as such. Live tree size class distributions from a number of existing studies and historical reports were used to contrast contemporary and historical estimates of biomass using equations (1) and (2).

Results and Discussion

Species presence

A post-harvest inventory (Table 1) showed that the number of overstory species in the sample area declined from 24 in 2006 (the most recent pre-harvest inventory) to 12 in 2009, with loblolly and shortleaf pine now comprising 59.26% of the remaining live trees (up from 16.24% in 2006). Two taxa not present in 2006, black hickory (Carya texana Buckl.) and white ash (Fraxinus americana L.), were found on the
Stand conditions immediately following a restoration harvest in an old-growth pine-hardwood remnant

2009 sample plots. These species were present in the LWDF prior to the restoration harvest, but simply were not tallied because they did not occur in the 2006 plots. Note that this current study did not sample the riparian management zone buffers along the main drainage of the LWDF. If this had been done (the 2006 study included plots in this zone), it is likely that a number of species would be added to the list.

The reduction of overstory diversity across much of this stand makes the LWDF more consistent with the patterns observed for the pine-dominated virgin forest of this region (Bragg 2002, 2004b). Historical records document a local (α) tree diversity of between 10 and 20 overstory species in upland forests (e.g., Olmsted 1902, Zon 1905, Garver and Miller 1933), although landscape (γ) diversity does not appear to have changed much over time, with scores of species found regionally in both the past and present (e.g., Bragg 2002, 2003).

Change in understory species composition is harder to quantify, since many of the taxa affected by the logging may actually remain but were covered by logging slash, while others were only top-killed. Additionally, many of the hardwood stumps were still alive and will probably sprout during the next growing season.

The dominance (>95%) of live woody plants remaining in the smallest understory size class (Table 2) will also prove to be fleeting, as the newly increased site resources produced by the opening of the canopy and removal of overstory competitors should permit advance reproduction and new germinants to grow rapidly. Historically, frequent fires maintained open understories in this portion of southern Arkansas, with patchy areas of pine and hardwood reproduction scattered amongst grasses, forbs, and areas of exposed mineral soil (e.g., Olmsted 1902, Record 1907, Bragg 2002, 2003).

Table 1. Species presence change (for live trees > 9.0 cm DBH) in the LWDF between the 2006 inventory (Bragg 2006) and the 2009 inventory conducted following the first restoration treatment of this stand.

<table>
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<tr>
<th>Species</th>
<th>Relative abundance (percent of total stems) in:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2006</td>
</tr>
<tr>
<td>Shortleaf pine (Pinus echinata Mill.)</td>
<td>4.18</td>
</tr>
<tr>
<td>Loblolly pine (Pinus taeda L.)</td>
<td>12.06</td>
</tr>
<tr>
<td>Red maple (Acer rubrum L.)</td>
<td>5.01</td>
</tr>
<tr>
<td>American hornbeam (Carpinus caroliniana Walt.)</td>
<td>0.37</td>
</tr>
<tr>
<td>Bitternut hickory (Carya cordiformis (Wang.) K. Koch))</td>
<td>0.72</td>
</tr>
<tr>
<td>Black hickory (Carya texana Buckl.)</td>
<td>0.00</td>
</tr>
<tr>
<td>Mockernut hickory (Carya tomentosa Nutt.)</td>
<td>1.09</td>
</tr>
<tr>
<td>Sugarberry (Celtis laevigata Willd.)</td>
<td>0.11</td>
</tr>
<tr>
<td>Flowering dogwood (Cornus florida L.)</td>
<td>2.26</td>
</tr>
<tr>
<td>Green ash (Fraxinus pennsylvanica Marsh.)</td>
<td>0.11</td>
</tr>
<tr>
<td>White ash (Fraxinus americana L.)</td>
<td>0.00</td>
</tr>
<tr>
<td>American holly (Ilex opaca At.)</td>
<td>0.23</td>
</tr>
<tr>
<td>Sweetgum (Liquidambbar styraciflua L.)</td>
<td>20.65</td>
</tr>
<tr>
<td>Red mulberry (Morus rubra L.)</td>
<td>0.49</td>
</tr>
<tr>
<td>Blackgum (Nyssa sylvatica L.)</td>
<td>7.99</td>
</tr>
<tr>
<td>Eastern hop hornbeam (Ostrya virginiana (Mill.) Koch)</td>
<td>0.37</td>
</tr>
<tr>
<td>Black cherry (Prunus serotina Ehrh.)</td>
<td>1.66</td>
</tr>
<tr>
<td>White oak (Quercus alba L.)</td>
<td>13.12</td>
</tr>
<tr>
<td>Southern red oak (Quercus falcata Michx.)</td>
<td>9.31</td>
</tr>
<tr>
<td>Cherrybark oak (Quercus pagoda Raf.)</td>
<td>1.20</td>
</tr>
<tr>
<td>Water oak (Quercus nigra L.)</td>
<td>2.26</td>
</tr>
<tr>
<td>Post oak (Quercus stellata Wang.)</td>
<td>0.60</td>
</tr>
<tr>
<td>Black oak (Quercus velutina Lam.)</td>
<td>1.80</td>
</tr>
<tr>
<td>Sassafras (Sassafras albidum (Nutt.) Nees.)</td>
<td>1.66</td>
</tr>
<tr>
<td>Winged elm (Ulmus alata Michx.)</td>
<td>11.57</td>
</tr>
<tr>
<td>Slippery elm (Ulmus rubra Muhl.)</td>
<td>1.20</td>
</tr>
</tbody>
</table>

* Since many of the original plot locations had been destroyed by the logging, a new series of plots were established during the fall, after many leaves had dropped. These “new” species could either be differences in identification between the inventories, or the inclusion of previously untallied taxa.
Table 2. Abundance of the live understory woody plants in the LWDF following the 2009 restoration harvest.

<table>
<thead>
<tr>
<th>Species</th>
<th>Number of stems per hectare by size class code</th>
<th>Totals by species</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Woody vines</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Virginia creeper (<em>Parthenocissus quinquefolia</em> (L.) Planchon)</td>
<td>357.1 0.0 0.0 0.0 0.0 0.0 357.1</td>
<td></td>
</tr>
<tr>
<td>Muscadine (<em>Vitis rotundifolia</em> Michx.)</td>
<td>1428.6 0.0 0.0 0.0 0.0 0.0 1428.6</td>
<td></td>
</tr>
<tr>
<td>Greenbrier (<em>Smilax</em> spp.)</td>
<td>2261.9 238.1 0.0 0.0 0.0 0.0 2500.0</td>
<td></td>
</tr>
<tr>
<td>Honeysuckle (<em>Lonicera</em> spp.)</td>
<td>357.1 0.0 0.0 0.0 0.0 0.0 357.1</td>
<td></td>
</tr>
<tr>
<td>Poison ivy (<em>Toxicodendron radicans</em> (L.) Kuntze)</td>
<td>1190.5 0.0 0.0 0.0 0.0 0.0 1190.5</td>
<td></td>
</tr>
<tr>
<td>Rattan (<em>Berchemia scandens</em> (Hill) K. Koch)</td>
<td>119.0 0.0 0.0 0.0 0.0 0.0 119.0</td>
<td></td>
</tr>
<tr>
<td><strong>Shrubs</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Vaccinium</em> spp.</td>
<td>952.4 0.0 0.0 0.0 0.0 0.0 952.4</td>
<td></td>
</tr>
<tr>
<td>American beautyberry (<em>Callicarpa americana</em> L.)</td>
<td>0.0 119.0 0.0 0.0 0.0 0.0 119.0</td>
<td></td>
</tr>
<tr>
<td><strong>Trees</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red maple</td>
<td>476.2 0.0 0.0 0.0 0.0 0.0 476.2</td>
<td></td>
</tr>
<tr>
<td>Blackgum</td>
<td>119.0 0.0 0.0 0.0 0.0 0.0 119.0</td>
<td></td>
</tr>
<tr>
<td>Black cherry</td>
<td>0.0 0.0 0.0 0.0 119.0 0.0 119.0</td>
<td></td>
</tr>
<tr>
<td>White oak</td>
<td>1190.5 0.0 0.0 0.0 0.0 0.0 1190.5</td>
<td></td>
</tr>
<tr>
<td>Southern red oak</td>
<td>357.1 0.0 0.0 0.0 0.0 0.0 357.1</td>
<td></td>
</tr>
<tr>
<td>Water oak</td>
<td>119.0 0.0 0.0 0.0 0.0 0.0 119.0</td>
<td></td>
</tr>
<tr>
<td>Post oak</td>
<td>119.0 0.0 0.0 0.0 0.0 0.0 119.0</td>
<td></td>
</tr>
<tr>
<td>Winged elm</td>
<td>952.4 0.0 0.0 0.0 0.0 0.0 952.4</td>
<td></td>
</tr>
<tr>
<td><strong>Totals by size class</strong></td>
<td>10000.0 357.1 0.0 119.0 0.0 0.0 10476.2</td>
<td></td>
</tr>
</tbody>
</table>

* Size class definitions: A (stems 15-74 cm tall); B (stems 75-136 cm tall); C (stems ≥ 137 cm tall but < 1.5 cm at DBH); 1 (stems 1.5-3.8 cm DBH); 2 (stems 3.9-6.3 cm DBH); and 3 (stems 6.4-9.0 cm DBH).

Tree size class distributions

While large pines were largely unaffected by the restoration, logging activities that targeted hardwoods seems to have reduced the small individuals of all species (Figure 2, Table 3). Of the nearly 350 live stems > 9.0 cm DBH per hectare in the 2006 inventory, only about 20% of these remained following the restoration treatment, of which most were pine (Table 4). The differences in pine abundance patterns between the 2006 and 2009 inventories (Figure 2) have several explanations—but not harvesting, because only a very small number of pines were cut. First, the sample plots were not in the same location between these inventories, which likely produced some of the pine differences. The LWDF sample of 2009 had a somewhat higher level of shortleaf pine (about 2 more stems per hectare, Table 4), but these did not arise as ingrowth since the last measurement. Second, there have been a number of pine that have died over the last few years, including canopy dominants killed by lightning strikes, windthrow, and bark beetles. Both loblolly and shortleaf pines experienced mortality during this period, but the data to compare which species may have succumbed at a higher rate are not available.

The absence of small diameter individuals of either pine species in the LWDF (Figure 2) is a well-documented phenomena witnessed in numerous mature, unmanaged pine-dominated forests across the region (e.g., Shelton and Cain 1999, Heitzman et al. 2004, Bragg and Heitzman 2009). In these stands, the hardwood under- and midstories have formed a closed canopy over the years, thereby shading out the shade-intolerant pine germinants. Coupled with a thick litter layer that inhibits pine seed germination, overstory recruitment of pine has all but ceased under these conditions. Presumably, the restoration treatment on the LWDF will open the canopy and prepare the seedbed sufficiently to trigger enough pine recruitment so the pine overstory can be sustained into the future.
Stand conditions immediately following a restoration harvest in an old-growth pine-hardwood remnant

Figure 2. Live tree size class distribution of a number of distinct taxonomic groups in the LWDF from before the restoration treatment (a) and immediately afterwards (b).

In the treated area, a much reduced fraction of hardwoods of all size categories remains, with most of these left to ensure that large canopy openings were not created by the harvest. Initially few in number in the 2006 inventory (Figure 2a), large diameter hardwoods were virtually eliminated in the treated area (Figure 2b)—very few were retained because of their value as sawtimber. Historical documentation (e.g., Zon 1905, Chapman 1913) of the virgin pine-dominated forests of this area rarely noted large (> 50 cm DBH) diameter hardwoods in the uplands. Rather, large hardwoods (many exceeding 100 cm DBH) tended to be much more common in the bottomlands and first terraces along minor streams, presumably where they received greater protection from the frequent surface fires of the presettlement period (Bragg 2002, 2003). Current

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Table 3. Comparison of the statistics of sampled live trees > 9.0 cm DBH in the LWDF.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average DBH (cm)</td>
<td>Standard deviation (cm)</td>
</tr>
<tr>
<td>Shortleaf pine</td>
<td>53.5</td>
<td>14.5</td>
</tr>
<tr>
<td>Loblolly pine</td>
<td>55.9</td>
<td>15.6</td>
</tr>
<tr>
<td>Red maple</td>
<td>12.3</td>
<td>3.7</td>
</tr>
<tr>
<td>American hornbeam</td>
<td>16.1</td>
<td>5.0</td>
</tr>
<tr>
<td>Bitternut hickory</td>
<td>22.7</td>
<td>17.1</td>
</tr>
<tr>
<td>Black hickory</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Mockernut hickory</td>
<td>22.4</td>
<td>8.4</td>
</tr>
<tr>
<td>Sugarberry</td>
<td>12.7</td>
<td>0.0</td>
</tr>
<tr>
<td>Flowering dogwood</td>
<td>12.3</td>
<td>2.7</td>
</tr>
<tr>
<td>Green ash</td>
<td>10.7</td>
<td>0.0</td>
</tr>
<tr>
<td>White ash</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>American holly</td>
<td>14.5</td>
<td>3.6</td>
</tr>
<tr>
<td>Sweetgum</td>
<td>23.5</td>
<td>11.2</td>
</tr>
<tr>
<td>Red mulberry</td>
<td>21.2</td>
<td>4.5</td>
</tr>
<tr>
<td>Blackgum</td>
<td>15.4</td>
<td>6.5</td>
</tr>
<tr>
<td>Eastern hop hornbeam</td>
<td>11.4</td>
<td>0.9</td>
</tr>
<tr>
<td>Black cherry</td>
<td>15.9</td>
<td>5.1</td>
</tr>
<tr>
<td>White oak</td>
<td>26.3</td>
<td>15.8</td>
</tr>
<tr>
<td>Southern red oak</td>
<td>26.5</td>
<td>10.3</td>
</tr>
<tr>
<td>Cherrybark oak</td>
<td>24.2</td>
<td>5.6</td>
</tr>
<tr>
<td>Water oak</td>
<td>34.2</td>
<td>17.4</td>
</tr>
<tr>
<td>Post oak</td>
<td>44.5</td>
<td>28.5</td>
</tr>
<tr>
<td>Black oak</td>
<td>19.8</td>
<td>5.9</td>
</tr>
<tr>
<td>Sassafras</td>
<td>17.4</td>
<td>4.3</td>
</tr>
<tr>
<td>Winged elm</td>
<td>15.1</td>
<td>6.1</td>
</tr>
<tr>
<td>Slippery elm</td>
<td>12.8</td>
<td>6.0</td>
</tr>
</tbody>
</table>

a Taxa not reported in the inventory of Bragg (2006).

plans for this restoration include the retention of streamside management zones along the larger of the drainages crossing this site, which should protect a limited number of the larger hardwoods.

Stand density and biomass

Between 2006 and 2009, overall stand density dropped from 28.2 m²/ha of basal area to 16.4 m²/ha (Table 4). Actual pine basal area changed little, with slightly more shortleaf and slightly less loblolly measured in 2009 (see earlier discussion on pine abundance). From a relative perspective, pine is now much more important overall—loblolly pine now constitutes 58% of stand live basal area, and shortleaf pine contributes 26%, for a total of 84% of the 16.4 m²/ha in the treated area. In 2006, loblolly made up 39% of stand basal area, and shortleaf constituted just 12%—hardwoods were truly codominant in the LWDF. Hardwood basal area declined most precipitously as a consequence of the restoration harvest deliberately targeting this group. For example, the three hardwoods with the highest basal areas in 2006 (sweetgum, 3.8 m²/ha; white oak, 3.4 m²/ha; and southern red oak, 2.1 m²/ha) were all reduced to between 0.7-0.8 m²/ha after the 2009 treatment, and none of the other hardwoods present exceeds 0.3 m²/ha.

As with historical accounts of species presence and abundance, the treated LWDF now better aligns with the virgin forest. While it is certain that past forest conditions covered a wide range of stand densities, historic pine forests seem less well stocked than contemporary examples. Most references (e.g., Mohr 1897, Olmsted 1902, Chapman 1913, Forbes and Stuart 1930) report between 10 and 20 m²/ha of basal area in presettlement pine-dominated forests, with occasional mention of higher totals (Bragg 2002, 2008). Bruner (1930, p. 23) identified frequent damaging fires as one of the principle reasons that old-growth pine forests in southeastern Arkansas averaged only about 50% “of their capacity”, with some stands only capable of one-third the stocking of protected stands. Given the multiple examples of unmanaged, old pine-hardwood forests in the vicinity of the LWDF that
Stand conditions immediately following a restoration harvest in an old-growth pine-hardwood remnant

Table 4. Stand-level attributes for sampled live trees > 9.0 cm DBH on the LWDF.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tree Basal frequency a</td>
<td>Biomass AG a (Mg/ha)</td>
<td>Biomass BG a (Mg/ha)</td>
<td>Tree Basal frequency a</td>
<td>Biomass AG a (Mg/ha)</td>
<td>Biomass BG a (Mg/ha)</td>
</tr>
<tr>
<td>Shortleaf pine</td>
<td>14.6</td>
<td>3.5</td>
<td>20,936</td>
<td>4,578</td>
<td>12.4</td>
<td>4.2</td>
</tr>
<tr>
<td>Loblolly pine</td>
<td>42.1</td>
<td>11.1</td>
<td>68,078</td>
<td>14,847</td>
<td>30.5</td>
<td>9.5</td>
</tr>
<tr>
<td>Red maple</td>
<td>17.5</td>
<td>0.2</td>
<td>1,119</td>
<td>0.260</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>American hornbeam</td>
<td>1.3</td>
<td>0.0</td>
<td>0.116</td>
<td>0.027</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Bitternut hickory</td>
<td>2.5</td>
<td>0.1</td>
<td>0.939</td>
<td>0.208</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Black hickory</td>
<td>-- b</td>
<td>0.5</td>
<td>0.1</td>
<td>0.460</td>
<td>0.102</td>
<td></td>
</tr>
<tr>
<td>Mockernut hickory</td>
<td>3.8</td>
<td>0.2</td>
<td>0.877</td>
<td>0.198</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Sugarberry</td>
<td>0.4</td>
<td>0.0</td>
<td>0.019</td>
<td>0.005</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Flowering dogwood</td>
<td>7.9</td>
<td>0.1</td>
<td>0.369</td>
<td>0.086</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Green ash</td>
<td>0.4</td>
<td>0.0</td>
<td>0.013</td>
<td>0.003</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>White ash</td>
<td>-- b</td>
<td>0.5</td>
<td>0.0</td>
<td>0.044</td>
<td>0.010</td>
<td></td>
</tr>
<tr>
<td>American holly</td>
<td>0.8</td>
<td>0.0</td>
<td>0.056</td>
<td>0.013</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Sweetgum</td>
<td>72.1</td>
<td>3.8</td>
<td>22,227</td>
<td>4,967</td>
<td>9.5</td>
<td>0.8</td>
</tr>
<tr>
<td>Red mulberry</td>
<td>1.7</td>
<td>0.1</td>
<td>0.290</td>
<td>0.066</td>
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<tr>
<td>Blackgum</td>
<td>27.9</td>
<td>0.6</td>
<td>2,834</td>
<td>0.648</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Eastern hophornbeam</td>
<td>1.3</td>
<td>0.0</td>
<td>0.044</td>
<td>0.010</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Black cherry</td>
<td>5.8</td>
<td>0.1</td>
<td>0.556</td>
<td>0.128</td>
<td>0.0</td>
<td>0.0</td>
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<tr>
<td>White oak</td>
<td>45.8</td>
<td>3.4</td>
<td>29,408</td>
<td>6,457</td>
<td>7.1</td>
<td>0.7</td>
</tr>
<tr>
<td>Southern red oak</td>
<td>32.5</td>
<td>2.1</td>
<td>16,103</td>
<td>3,580</td>
<td>8.6</td>
<td>0.8</td>
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<tr>
<td>Cherrybark oak</td>
<td>4.2</td>
<td>0.2</td>
<td>1,412</td>
<td>0.318</td>
<td>0.5</td>
<td>0.0</td>
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<tr>
<td>Water oak</td>
<td>7.9</td>
<td>0.9</td>
<td>8,266</td>
<td>1,806</td>
<td>1.4</td>
<td>0.2</td>
</tr>
<tr>
<td>Post oak</td>
<td>2.1</td>
<td>0.4</td>
<td>4,466</td>
<td>0.963</td>
<td>0.5</td>
<td>0.1</td>
</tr>
<tr>
<td>Black oak</td>
<td>6.3</td>
<td>0.2</td>
<td>1,369</td>
<td>0.310</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Sassafras</td>
<td>5.8</td>
<td>0.1</td>
<td>0.647</td>
<td>0.149</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Winged elm</td>
<td>40.4</td>
<td>0.8</td>
<td>3,791</td>
<td>0.869</td>
<td>0.5</td>
<td>0.0</td>
</tr>
<tr>
<td>Slippery elm</td>
<td>4.2</td>
<td>0.1</td>
<td>0.280</td>
<td>0.064</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Totals</td>
<td>349.2</td>
<td>28.2</td>
<td>184.2</td>
<td>40.6</td>
<td>72.4</td>
<td>16.4</td>
</tr>
</tbody>
</table>

a AG = aboveground; BG = belowground. All biomass values represent oven-dry weights.

b Taxa not reported in the inventory of Bragg (2006).

exceed 30 m²/ha (e.g., Heitzman et al. 2004, Bragg 2004c, Bragg and Heitzman 2009, Bragg and Shelton in press), the treated area of the LWDF now represents a unique reflection of past conditions.

Total live biomass also fell from 224.8 Mg/ha in 2006 to 130.1 Mg/ha in 2009 (Table 4). Prior to the restoration, pine comprised just over 48% of total live biomass, or slightly less than the pine:hardwood basal area ratio found in 2006, a difference largely attributable to the higher specific gravity of hardwoods. Following the harvest treatments, pine now dominates the live tree biomass on the LWDF, with 81% of the total (Table 4). The ~225 Mg/ha of live tree biomass in the preharvest LWDF is somewhat lower than the quantity calculated for a number of other nearby mature, unmanaged pine-dominated stands (234-317 Mg/ha, e.g., Heitzman et al. 2004, Bragg 2004c, Bragg and Heitzman 2009, Bragg and Shelton in press). This difference is not dramatic, and may have arisen because of recent losses in the LWDF from windthrow and bark beetles (Bragg 2006). The post-restoration biomass total (~130 Mg/ha) is within the 54-170 Mg/ha range derived from the more detailed historical accounts of pine-dominated virgin stands in this region (e.g., Olmsted 1902, Zon 1905, Chapman 1913, Forbes and Stuart 1930, Garver and Miller 1933).

Hardwood age structure

While most of the pines in the LWDF are between 100 and 200 years old (Bragg 2006), a ring count sample of 102 randomly selected freshly cut hardwood stumps produced only one greater than 100 years. Two-thirds of these hardwoods were less than 70 years old, having originated after the stand was set aside by the Crossett Lumber Company in 1939 (Figure 3). It appears that the vast majority of hardwoods appeared between 1930 and 1970, after which the recruitment of hardwoods declined. The start of this pulse (the 1930s, represented by the 71-80 year age class) coincides with
the implementation of effective fire control in the Ashley County area by the Crossett Lumber Company and the then newly created Arkansas State Forestry Commission (Reynolds 1980). Note that it is likely that logging impacts and the sample design have caused underestimates in the number of young (<21 year old) hardwoods.

Figure 3. Hardwood stump ring counts from the LWDF by 10-year age classes.

The limited hardwoods found in the LWDF prior to 1939 were present either as recent germinants or scattered large trees contemporaneous with the pine overstory. The sample of hardwood stumps examined for this study did not find any with more than 127 rings, but given the presence of large hardwoods (primarily oaks) with external indications of old age (e.g., gnarled branches and boles, large cavities, smoothed bark) in other parts of the LWDF, it is apparent that at least a few hardwoods greater than 150-200 years old are present.

**Ground cover**

True before-and-after comparisons of ground cover are not possible, given that the data collected in this study were taken in different locations at different times. However, the approximations possible by comparing the treated and untreated areas of the LWDF suggest that these differences in ground cover resulted from the restoration treatment. The key attribute of the ground coverage is the proportion of exposed mineral soil found during the post-harvest inventory—prior to this logging, there would have been virtually no exposed soil on this site, save the occasional tree-tip-up mound or washed-out spot along the small streams that drain this area. As apparent in Table 5, substrate condition has changed considerably as a function of this harvest activity.

Table 5. Estimates of ground cover in unharvested areas and in plots after restoration harvest in the LWDF.

<table>
<thead>
<tr>
<th>Substrate</th>
<th>Percent cover</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before</td>
<td>After</td>
</tr>
<tr>
<td>Mineral soil</td>
<td>0.1</td>
</tr>
<tr>
<td>Live vegetation</td>
<td>3.7</td>
</tr>
<tr>
<td>Large woody debris</td>
<td>0.5</td>
</tr>
<tr>
<td>Litter</td>
<td>95.6</td>
</tr>
<tr>
<td>Standing water</td>
<td>0.0</td>
</tr>
</tbody>
</table>

"Before" coverage estimate actually uses nearby untreated parts of the stand to proxy preharvest conditions.

From almost 96% coverage in the uncut areas, litter and duff declined to just under 77%, with marked increases in mineral soil exposure (up to 13.6% from 0.1%) and large woody debris (up to 4.2% from 0.5%). Both of these are to be expected—the process of felling and skidding trees abrades the ground surface, exposing soil in many places and varying the thickness of the leaf litter in others (by either scraping it off or piling it up). Logging also adds a considerable quantity of branches, tops, and large pieces of waste wood to the site, although this was not as pronounced in this particular treatment due to the removal of much of this material for chipping.

Harvest activities also likely increased the number of places (e.g., tire ruts, log skid marks) for water to collect compared to untreated portions of the stand, but the small increase of this substrate (Table 5) also reflects differences in stand wetness due to precipitation patterns. The slight difference in live vegetation cover probably arose from the timing of the sampling—the post-harvest treatment was done in the fall when much of the live vegetation still had foliage, whereas the untreated sample was collected in early spring prior to leaf-out.

**Conclusions**

Native hardwood encroachment (densification) is one of the most significant concerns facing those managing for pine-dominated ecosystems. For instance, Masters et al. (2007) reported the loss of pure pine stands in an old-growth preserve in southeastern Oklahoma over the last half-century following effective fire suppression. Similar changes have been
Stand conditions immediately following a restoration harvest in an old-growth pine-hardwood remnant

reported across the southeastern U.S. (e.g., Quarterman and Keever 1962, Halls and Homesley 1966), usually in conjunction with the alteration of historic fire regimes. However, growing human populations, landscape fragmentation, smoke management issues, and air quality concerns are likely to limit the extensive use of controlled burning as an ecosystem management tool. In many instances, especially in more developed areas, land managers will need to work with other means to restore their properties.

One of the most obvious outcomes of this particular restoration effort is that the LWDF has experienced dramatic decreases in overstory richness, stand density, and live tree biomass, all of which may have consequences for other large-scale ecosystem management goals. For example, recent studies have promoted the retention of multi-aged, complex, species-rich old-growth forests in certain areas because of their capacity for in situ carbon storage and role as biodiversity reserves (e.g., Harmon et al. 1990, Carey et al. 2001, Luysaart et al. 2008, Keith et al. 2009). However, it is possible that the restoration of some forests to conditions similar to presettlement stand structure, such as done in this example, may reduce arboreal diversity and carbon storage. If this is the case, then measures of the relative success or failure of the treatments must be judged accordingly, especially when done on a large scale.

Regardless of these measures of restoration efficacy, the mechanical manipulation of the forest via partial cutting appears to have been effective in achieving certain goals. Although logging does not duplicate many of the ecological attributes of fire and imposes other influences (e.g., soil disturbance) not typically seen with burning, it did permit the landowner to rapidly change stand structure and composition in a controlled, smoke-free process. Once established, large hardwoods are also very hard to eliminate from a stand with fire, requiring a burn intensity that often kills large pines as well. The LWDF will also experience a strong woody understory response during the next few years, requiring the use of additional treatments to maintain the open, herbaceous cover that dominated pre-settlement stands.

Historical documentation and more recent research, combined with this preliminary assessment, suggests that the arboreal component of the LWDF is now more comparable in status to pre-settlement pine-dominated forests of southern Arkansas, which generally had lower stocking, less biomass, and fewer hardwoods than mature, unmanaged pine-hardwood stands of the present-day.

Acknowledgments

I would like to recognize the efforts of Kirby Sneed (US Forest Service) on the field measurements of this study. Richard Stich and Conner Fristoe of Plum Creek Timber Company graciously allowed access to this site and described their restoration plans. Mike Shelton and Nancy Koerth reviewed this paper and provided many helpful comments. This manuscript was written by a US government employee on official time, and is therefore in the public domain.

Literature cited


Gill HV, DC Avery, FC Larance, and CL Fultz. 1979. Soil survey of Ashley County, Arkansas. USDA Soil Conservation Service, USDA Forest Service, and the Arkansas Agricultural Experiment Station. 92 p.


Stand conditions immediately following a restoration harvest in an old-growth pine-hardwood remnant

Record SJ. 1907. The forests of Arkansas. Forestry Quarterly 5:296-301.


Tributary contribution to the Spring River, AR as determined by water quality analyses

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Abstract

Tributaries often play an important role in the chemical properties, productivity and species diversity in a river channel. The objective of this study was to analyze the effect of tributaries on the water quality of the Spring River, AR. The Spring River has an approximate length of 92 km and has been divided into four zones according to the water source(s) that feed that segment of river. In this study approximately 30 km of the upstream river segment were sampled, which included nine tributaries contributing to the main river channel and incorporated the upper three previously defined zones. Samples were collected from the headwaters located at Mammoth Spring, AR, as well as within the tributaries and above and below the confluence of each tributary with the Spring River.

Water-quality parameters analyzed included pH, conductivity, alkalinity, total suspended solids, fecal coliforms, nutrients (orthophosphate, nitrate, nitrite), and total dissolved ions. Results of total dissolved ions indicated a slight shift in the defined zones. Seven of the nine tributaries indicated chemical contributions ranging from 3.5 to 66.7% to the main stream. Results from this study demonstrate the extent of tributary contribution to the Spring River systems.

Introduction

Tributaries may affect water quality of the receiving waterway. This influence is dependent upon the properties of the tributary catchments (Rice et al. 2001). Previous studies have reported that the junctions between tributaries and main stream have high biodiversity (Benda et al. 2004, Kiffney et al. 2006). It is clear that tributaries have the potential to effect the waterways into which they feed.

The Spring River, located in north central AR, originates from Mammoth Spring, AR. Mammoth Spring is fed from the Ozark Plateau Aquifer and is recharged from rainwater infiltration (Vineyard and Feder 1982).

The drainage area that recharges this aquifer is located in south central MO. Research suggests that fecal coliform and nutrient loading are threats to surface waters in this agriculturally dominated area (Wilkerson 2000). The portion of the Spring River catchment located in Missouri is approximately 1244 km² and land use consist primarily of grassland/cropland (49.1%) and forest/woodland (48.3%) (Wilkerson 2000). The portion of the catchment located in Arkansas is approximately 1992 km² and land use consist primarily of forest (65.7%) and grassland (26.2%) (ArkansasWater.org 2010). Hannigan and Bickford (2003) noted that the Spring River and its tributaries are largely unpolluted and any potential contamination would be from agricultural run-off in the north and western tributaries.

The Spring River is unique when compared to traditional first order-second order streams as described in the RCC (Vannote et al. 1980) due to its headwater domination by a single source, Mammoth Spring. The river, with a reach of approximately 92 km, has been divided into four unique zones based upon hydrological differences determined by varying proportions of end-member water types (Hannigan and Bickford 2003).

Hannigan and Bickford (2003) used end-member mixing analysis (EMMA) and binary mixing/mass balance calculations to define three water types that
dominate the Spring River: groundwater, overland/subsurface flow and bank storage. The mixture of these three water types was found to be responsible for streamwater chemistry of the Spring River. They concluded that further exploration was needed to constrain the hydrochemistry of the river (Hannigan and Bickford 2003).

The Spring River and five related tributaries, Field Creek, Big Creek, English Creek, Myatt Creek and Gut Creek, are designated as Extraordinary Resource Streams (APCEC 2007). The Spring River has additionally been designated as an Ecologically Sensitive Waterbody (APCEC 2007). Its uses include primary contact, person full body (swimming) and secondary contact, person partial contact (wading), recreation and fisheries as well as a water supply for domestic, agriculture and industry (APCEC 2007).

The objective of this study was to determine the chemical and bacteriological influences of tributaries on a stretch of the Spring River. Using a combination of methods, the contribution of each tributary to the river was determined.

Materials and Methods

Study Site

Headwaters of the Spring River are dominated by Mammoth Spring which contributes approximately $3.4 \times 10^5$ m$^3$ water/hour (Hannigan and Bickford 2003). Approximately 30 km of the upstream reach and contributing tributaries were sampled which included three of the defined zones. The headwaters, Mammoth Springs (MS) and nine total tributaries were sampled: Warm Fork (TWF), tributary two (T2), Field Creek (TFC), Big Creek (TBC), English Creek (TEC), Myatt Creek (TMC), Gut Creek (TGC), Scrabble Creek (TSC) and South Fork (TSF) (Figure 1). Samples were collected on June 2-3, 2009, and according to hydrograph records for gage 07069305 located in Hardy, AR, this followed a streamflow peak on May 26-27, 2009 (USGS 2010). This may indicate that sampling occurred during conditions above baseflow. Samples were collected upstream of the disturbed substrate.

![Figure 1: Map showing sampled headwater source, MS and nine contributing tributaries of Spring River AR. Shapes indicate zones defined as defined by ion chemistry and tributary input: triangle (zone 1), diamond (zone 2) and circle (zone 3). Tributaries are not drawn to scale of actual length.](image)

Methodology

Following collection, samples were packed on ice and transported to Arkansas State University Ecotoxicology Research Facility for analysis. Subsamples were filtered and preserved for nutrient and total dissolved ion analysis (TDIs) (APHA 2005). Water quality measurements included pH, conductivity (µS/cm), total suspended solids (TSS) (mg/L), fecal coliform (colony forming units: CFU/100mL), alkalinity (CaCO$_3$/L; mEq), nutrients (NO$_2^-$, NO$_3^-$, PO$_4^{3-}$; mg/L) and TDIs (mEq). DO, pH, and conductivity were measured using a VWR SympHony field meter and conductivity was normalized at 18°C (Smith 1962). All water quality measurements followed the APHA guidelines and holding times (APHA 2005). The evaluation of fecal coliform presence in water samples was accomplished by enumerating the number of blue colonies after a 24h incubation period using rosalic acid as a growth medium. Alkalinity was determined using a potentiometric titration technique, with the pH endpoint of 4.5.

Levels of NO$_2^-$, NO$_3^-$ and PO$_4^{3-}$ were determined using a LACHET Quikchem 4000 Flow Injection Analysis (FIA) automated nutrient analyzer. The method used for NO$_2^-$ and NO$_3^-$ had a detection limit of 0.1 mg/L. Method used for PO$_4^{3-}$ had a detection limit of 0.01 mg/L.
TDIs were determined with a Dionex DX-120 Ion Chromatograph (IC) using established procedures at Arkansas State University (Greenberg et al. 1992). Major ions measured included cations (K$^+$, Na$^+$, Mg$^{2+}$, Ca$^{2+}$) and anions (Cl$^-$, NO$_3^-$, SO$_4^{2-}$, PO$_4^{3-}$). A five point calibration curve was determined using cation and anion aqueous standards. Charge-balance error was calculated for each site to check accuracy of water-quality data (Freeze and Cherry 1979). Ca$^{2+}$ and Mg$^{2+}$ concentrations (mEq) were compared with alkalinity values. These two ions were chosen based on rock formulas for limestone and dolomite. This was done to determine the influence of bedrock lithology on stream chemistry.

Percent contribution for individual tributaries compared to the main stream was calculated by using concentration values of a conservative ion, Cl$^-$ (mEq/L) with the following formula:

$$N_1(x) + N_2(1-x) = N_3$$

where 
- $N_1$ = Cl$^-$ concentration in the main stem above the tributary 
- $N_2$ = tributary Cl$^-$ concentration 
- $N_3$ = Cl$^-$ concentration below the confluence of the tributary with the main stem

The determined $x$ value, fraction contribution of main stream, was then multiplied by 100% to calculate the percent contribution of the main stream. This value was subtracted from 100 to determine percent contribution of individual tributaries.

**Results**

In all water quality measurements, pH ranged from 7.00-8.38, conductivity from 288-544 µS/cm at 18°C, and TSS from 1.5-28.5 mg/L. The lowest fecal coliform value was enumerated at 6 CFU/100mL and two sites were above allowable levels determined by the APCEC for the primary contact waters (APCEC 2007) (Table 1). Alkalinity ranged from 4.0-6.4 mEq/L (Table 2).

NO$_3^-$ and PO$_4^{3-}$ indicated a downward trend from the mouth of the river, MS, to the lowest collection point, TSF DN (NO$_3^-$ $R^2$=0.77, PO$_4^{3-}$ $R^2$=0.65) (Figure 2 and 3, respectively). There were no detectable levels of NO$_2^-$ in any of the samples measured. NO$_3^-$ ranged from below detection limit to 4.88 mg/L in water sampled from MS. Three of the nine tributaries contributed detectable levels of NO$_3^-$: TWF, T2, and TFC. PO$_4^{3-}$ ranged from 0.01-0.11 mg/L with the greatest value detected in water from TWF DN. All tributaries contributed detectable levels of PO$_4^{3-}$ (Table 1).

The cations K$^+$, Na$^+$, Mg$^{2+}$ and Ca$^{2+}$ ranged from 0.01-0.04 mEq/L, 0.01-0.07 mEq/L, 2.44-3.89 mEq/L and 1.93-3.47 mEq/L, respectively. The anion F$^-$ was consistent at 0.02 mEq/L for all samples. The remaining anions Cl$^-$ and SO$_4^{2-}$ ranged from 0.05-0.12 mEq/L and 0.04-0.12 mEq/L, respectively.

Charge-balance error for all sample sites, with the exception of T2 UP, T2, TGC and TSC, fell within the accepted +/- 5%. All site charge-balance errors fell below 7.8%. Total dissolved ions (TDIs) ranged from 8.72 to 13.97 mEq/L. The highest values were detected in the tributaries with the exception of...
Tributary contribution to the Spring River, AR as determined by water quality analyses

Table 1: Water quality measurements for pH, conductivity, total suspended solids (TSS), fecal coliforms and nutrients measured from the headwaters, tributaries and main channel of the Spring River, AR. Downstream denoted by (DN) and upstream by (UP). Below detection limit (BDL). Cumulative distance (km) is descriptive of the main channel. Cumulative distance for tributaries is the location at which the tributary enters the main channel.

<table>
<thead>
<tr>
<th>Cumulative Distance (km)</th>
<th>Sample Site</th>
<th>pH</th>
<th>conductivity (µS/cm)**</th>
<th>fecal coliform (CFU/100mL)</th>
<th>TSS (mg/L)</th>
<th>PO₄³⁻ (mg/L)</th>
<th>NO₃⁻ (mg/L)</th>
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<tr>
<td>0.0</td>
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<td>0.03</td>
<td>1.09</td>
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<td>0.11</td>
<td>2.65</td>
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<td>T2 UP</td>
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<td>288</td>
<td>109</td>
<td>6.6</td>
<td>0.06</td>
<td>3.45</td>
</tr>
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<td>446*</td>
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<td>0.03</td>
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<td>5.90</td>
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<td>800*</td>
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<td>0.02</td>
<td>0.91</td>
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*exceeds maximum allowable level for primary contact recreational designation

**conductivity normalized at 18°C

TSF, which had the lowest value of 8.72 mEq/L (Table 2). Comparison of Ca²⁺ and Mg²⁺ concentrations with measured alkalinity indicated a clustering in tributary contribution based on bedrock lithology and the delineation of three spatially distinct zones (Figure 4).

Seven of the nine tributaries were determined to have a detectable contribution to the Spring River based on the concentration of Cl⁻ (mEq/L) (Table 2).

Discussion

To protect Ecologically Sensitive and Extraordinary Resource Waterbodies, it is important to understand the influence of tributaries on these systems. The Spring River has been designated as a primary and secondary contact waterway, so direct human contact is expected.
The primary contact designation allows a maximum level of fecal coliform at 400 coliforms/100mL (APCEC 2007). In this study, T2 bordered that level while TFC was double the allowable level. It was observed that agricultural grazing land bordered both sides of T2, and construction and clearing of land was occurring at time of collection around TFC. High fecal coliform levels contributed only slightly to the main stream as dilution occurred below the confluence. The size of the river compared to the contribution from these two tributaries may have been key in keeping the levels of fecal coliforms below the acceptable limit in the main stem of the Spring River.

Minshall et al. (1985) stated that a tributary may dilute mainstream nutrient concentrations. Results of nutrient analysis in this study indicate that tributaries were diluting the river and lowering detected levels as \( \text{NO}_3^- \) and \( \text{PO}_4^{3-} \) values followed a decreasing pattern starting at or near the mouth of the river (Mammoth

Table 2: Water measurements including ion, alkalinity, total dissolved ions (TDI) and tributary contribution. Downstream denoted by (DN) and upstream by (UP). Percent tributary contribution is calculated on an individual basis at point of entry to mainstream.

<table>
<thead>
<tr>
<th>Cumulative Distance (km)</th>
<th>Sample Site</th>
<th>Cations (mEq/L)</th>
<th>Anions (mEq/L)</th>
<th>Alkalinity (mEq/L)</th>
<th>TDI* (mEq/L)</th>
<th>Tributary Contribution (%)</th>
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<td>0.0</td>
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<td>6.4 13.97</td>
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<td>2.24 0.02 0.05 0.11</td>
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*TDIs includes \( \text{NO}_3^- \) and \( \text{PO}_4^{3-} \) values from Table 1. Values were converted to mEq/L prior to summation.

**charge-balance error does not fall within recommended +/- 5% (Freeze and Cherry 1979). T2 UP 5.7%, T2 5.8%, TGC 7.8% and TSC 7.2%..
Wilkerson (2000) suggested that nutrient loading may occur in the rural drainage area that recharges the aquifer that feeds MS. This statement is supported in this study as the highest nutrient levels were measured at or near the mouth of the Spring River. This result also indicates the importance of tributary contribution.

The TDIs were higher in the tributaries (with the exception of TWF and TSF) which are smaller than the main stream. The difference in TDIs may be a result of the shallower tributaries having greater water/rock interactions.

Figure 4: Ratio of alkalinity ($\text{CaCO}_3$, mEq/L) and sum of $\text{Ca}^{2+}$ (mEq/L) and $\text{Mg}^{2+}$ (mEq/L) for the main stream indicating that spatially distinct zones occur within the Spring River.

The unique zones determined in the present study (Figure 4), MS (Zone 1), TWF DN to TEC UP (Zone 2) and TEC DN to TSF DN (Zone 3), were consistent with the three zones defined for this particular stretch of the river with one exception. Hannigan and Bickford (2003) categorized TWF DN in Zone 1, but our analyses classified it into Zone 2. In their study, in which monthly samples were taken over a 12 month period, zones were based upon two contributing endmembers, groundwater and overland/subsurface. Hannigan and Bickford (2003) also noted that although TWF added warmer water in the summer, the domination of groundwater in this zone quickly diluted any chemical additions. The shift in Zone 2 to include TWF DN may indicate that TWF is playing a larger role the Spring River system than previously thought. This is also supported by the 47% contribution by TWF to the main stream. This present study employed a single sampling event and, based on ion chemistry and tributary input, closely confirmed the previously defined zones. The unique zoning may indicate that the tributaries in the Spring River system are resulting in discontinuities in the continuum of the river as described by Perry and Schaeffer (1987) and Rice et al. (2001).

Conclusion

Due to the atypically large headwater source of this river system compared to a traditional first order-second order streams as described in the RCC tributary effect may be underestimated compared to more traditional systems (Vannote et al. 1980). In a traditional system the headwaters and contributing tributaries are more comparable in size. With the increase in stream order, the main stream is typically larger than the contributing tributaries. The uniqueness of this river system should be taken into consideration when comparing the results of this study to results obtained for other, more typical streams.

Additional research may help to establish if the tributaries are causing discontinuities in this system. An important investigation would be to determine if differences in biota exist in the various zones of the Spring River, AR.

Acknowledgments

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Literature Cited


Kiffney PM, CM Greene, JE Hall, and JR Davies. 2006. Tributary streams create spatial discontinuities in habitat, biological productivity, and diversity in mainstem rivers. Canadian Journal of Fisheries and Aquatic Sciences 63:2518-30.


Seasonal Activity of the Ozark Highlands Leech, *Macrobdella diplotertia*, (Annelida: Hirudinea) in North-central Arkansas

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Abstract

The Ozark Highlands Leech, *Macrobdella diplotertia*, occurs intermittently throughout Arkansas, Kansas, and Missouri. Limited natural history of this species is known. Herein, we report a new county occurrence for this leech from a cattle pond in southern Marion County, Arkansas. We also report on the seasonal activity and novel hosts of this species. We surveyed the inhabited pond monthly to determine activity and collected natural history data on this species. This study indicated that this species appears to be most active in spring, summer, and early fall, but inactive during the winter. We also documented five new anuran hosts for this species. The Central Newt, *Notophthalmus viridescens*, was also present in this pond, which further supports a mimetic relationship previously proposed between these two animals.

Introduction

There are currently 77 described species of leeches occurring in North American north of Mexico (Klemm et al. 2009). Of these 77 species, 22 are known to occur in Arkansas (Moser et al. 2006). The distribution and natural histories of many of these species have yet to be determined completely (Klemm 1985). Herein, we report on the natural history of one of these species, the Ozark Highlands Leech (*Macrobdella diplotertia*). *Macrobdella* is a monophyletic genus with four species in North America (Phillips and Siddall 2005). Two species of *Macrobdella* occur in Arkansas, *M. diplotertia* in the north and *M. ditetra* in the south (Moser et al. 2006). *M. diplotertia* has been previously reported from two counties in Missouri (Meyer 1975, Trauth and Neal 2004), three counties in Kansas (Klemm et al. 1979) and two counties in Arkansas (Turberville and Briggler 2003). No additional specimens, however, were discovered during a leech survey of northern Arkansas (Moser et al. 2006).

*Macrobdella diplotertia* is an omnivore known to be an amphibian egg predator and a sanguivore (Turberville and Briggler 2003, Trauth and Neal 2004). It is also known to have a mimetic relationship with the Central Newt (McCallum et al. 2008). Interestingly, the leech *Placobdella picta* has been observed attached to the Ozark Highlands leech (Turberville and Briggler 2003). Currently, no reports of these leeches feeding on adult amphibians have been published.

Methods

Leeches were observed and collected in a manmade cattle pond in southern Marion County, Arkansas (UTM 15N 0535878E, 3992944N). In order to obtain data on seasonal activity of the leeches, the pond was surveyed monthly during daylight hours for a year from June 2009 to May 2010. One of the authors (MBC) slowly walked around a section of the pond perimeter (~25 m) at a water depth of ~30 cm for 10 min each month and collected all observed leeches with a ~6 mm mesh dipnet. To supplement the survey, 5 single dipnet collections of the benthic substrate were collected every month and sifted through to collect any leeches in this material. We also opportunistically captured amphibians and examined them for leech parasitism. We also sampled the pond for the presence of Central Newts to provide further support of the proposed mimetic relationship between these two species (McCallum et al. 2008). All collected leeches were deposited in the Invertebrate Zoology collections of the National Museum of Natural History, Smithsonian Institution, Washington, DC, for further studies.

Results

Marion County (Arkansas) represents a new county occurrence for *M. diplotertia* (Fig. 1). We recorded these leeches to be most active in spring, summer, and early fall, but inactive during the winter...
Figure 1: Distribution of the Ozark Highlands Leech (*Macrobdella diplotertia*) in Kansas, Missouri, and Arkansas. Previous records (dots); new record (star).

During the warmer months, leeches were collected while freely swimming in the pond. The leeches were documented to feed on the eggs of gray treefrogs (*Hyla versicolor*) *in situ*. We also observed these leeches to feed from five novel adult anuran host species: Spring Peeper (*Pseudacris crucifer*); Gray Treefrog; Pickerel Frog (*Lithobates palustris*); Green Frog (*L. clamitans*); and American Bullfrog (*L. catesbeianus*). An adult leech was attached to the gular region of the Spring Peeper. An adult leech was attached adjacent to the orbit of the eye on the treefrog. A juvenile was attached to the inner thigh of the bullfrog. While in captivity directly after collection, we observed an adult leech attach to the dorsal cephalic region of a Spotted Salamander (*Ambystoma maculatum*) larva and feed there. Additionally, while in captivity we observed two different individuals attach to the web of the hind foot of a Pickerel frog and Green frog. We also observed on several occasions, we observed the leech *Placobdella picta* attached to *Macrobdella diplotertia*. The Central Newt was very common within the pond providing further evidence for potential interactions between these two species.

**Discussion**

The discovery of this population of *Macrobdella diplotertia* in Marion County expands the distribution of this species eastward in Arkansas. Other populations may occur elsewhere within the Ozark Highlands region in the state. Amphibians that either live or reproduce within ponds that contain populations of these leeches may sustain substantial parasitism; however, the extent of this parasitism is currently unknown. The observations of both amphibian adult and egg predation suggest that *M. diplotertia* affect the fitness of adult amphibians as well as survival of developing larvae.

The genus *Macrobdella* typically feed on amphibian adults and their larvae. *M. decora* has been reported feeding on brook trout, *Salvelinus fontinalis* (Rupp and Meyer 1954) and amphibian eggs, including *Ambystoma maculatum* (Cargo 1960), *Bufo terrestris* (Travis and Trexler 1986), *Lithobates catesbeianus* (Howard 1978), and *L. sylvatica* (Cory and Manion 1953). *M. ditetra* has been reported feeding on sirens, *Siren intermedia*, (Graham and Borda 2010) and southern leopard frogs, *L. sphenocephala* (Beckerdite and Corkum 1973). An unusual case of hirudiniasis was reported with *M. ditetra* feeding on cattle, *Bos taurus* (Meyer 1959). Moore (1953) reported that *M. ditetra* readily consumed the eggs of *L. catesbeianus*. Because *M. sestertia* is quite rare, host preferences have not been determined, although Smith (1977) stated that beach patrons reported that these leeches commonly fed on humans. By combining our results with those of Trauth and Neal (2004) and Turbeville and Briggler (2003), *M. diplotertia* is now known to feed on adult...
amphibians, including Spring Peepers, Gray Treefrogs, Pickerel Frogs, Green Frogs, and American Bullfrogs, as well as the eggs of five amphibian species (A. maculatum, H. versicolor, L. clamitans, L. sphenocephala, and L. sylvatica). Our results have augmented the known food sources for M. diplotertia, although further studies are required to assess the impact this species has on amphibian fitness and survival.

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Literature Cited


Biosensors for Biodiesel Quality Sensing

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Abstract

A biosensor is an analytical device that uses biomaterials as elements of the sensing system and converts a biological response into an electrical signal. Biodiesel is a bio-based alternative, biodegradable, renewable, nontoxic diesel fuel made from a chemical reaction between alcohol (usually methanol or ethanol) and plant oil or animal fat. A need to provide accurate, real-time information for the quality sensing of biodiesel properties such as free and total glycerol has led to an ever-increasing demand for biosensor development. Being able to monitor specific physical and chemical properties is the prerequisite for developing a biosensor for quality sensing of the biodiesel. This article proposes a method for detection of the blend level of degraded biodiesel and lipase as a bioelement of biosensor systems. A design of an electrochemical potentiometric biosensor for quality sensing of biodiesel properties is proposed and discussed in detail. However, experimental trials, actual implementation and evaluations are necessary to understand the feasibility of the proposed biodiesel biosensor.

Keywords: Biosensor, biodiesel, lipase, enzymatic hydrolysis, immobilization, glycerol, quality sensing.

Introduction

A biosensor is a self-contained integrated device that is capable of providing specific quantitative or semi-quantitative analytical information using a biological recognition element that is in direct spatial contact with a transduction element (IUPAC 1996). Thus, a biosensor is a combination of two elements: the bioelement and the transducer or sensor element (Fig. 1).

Many biologically important biospecies such as enzymes, proteins and antibodies can be used as biological elements of recognition (bioelements) for biosensors (Zen et al. 1997, Lin and Shih 1999, Chang and Shih 2000, Chou et al. 2008). Enzymes are large, complex macromolecules, consisting largely of protein and usually contain a prosthetic group (one or more metal atoms). Enzymes hydrolyzing triglycerides have been studied for well over 300 years, and the ability of the lipases to catalyze the hydrolysis and synthesis of esters was recognized nearly 70 years ago (Hasan et al. 2006).

Lipase (EC 3.1.1.3) is a member of the broad classification of hydrolases, which transfer functional groups to water. Lipases are characterized by the ability to hydrolyze the long chain triglycerides or triacylglycerol (TAG) at an oil-water interface, resulting in the formation of fatty acids (Van Gerpen 2007, Hasan et al. 2006). The presence of lipases was observed as early as 1901 (Eijkman 1901) for Bacillus prodigiosus, B. pyocyaneus and B. fluorescens (now named Serratia marcescens), which represent today’s best-studied lipase-producing bacteria, Pseudomonas aeruginosa and Pseudomonas fluorescens. Lipases isolated from different sources have a wide range of properties with respect to positional specificity, fatty-acid specificity, thermostability and optimum pH (Huang 1984).
Biofuel is one of the most rapidly growing renewable energy sources. Bioenergy is stored during photosynthesis mainly in seed. Plants store oil as a dense form of energy that helps seed germination and early stage plants roots establishment. When the same oil is burned in a diesel engine, the oil releases its stored energy to power the vehicle. Biodiesel consists of the monoalkyl esters of long-chain fatty-acids produced by transesterification of triglycerides with primary alcohols in the presence of a catalyst (Fig. 2) (Knothe et al. 2005). The biodiesel production process can be summarized as a chemical reaction between primarily methanol or ethanol and an oil or fat. Biodiesel can be both cost and energy efficient to produce and can replace petroleum fuel in buses, trucks, tractors and cars with diesel engines (Tat and Van Gerpen 2003). Vegetable oils and animal fats are the only sources of triglycerides used in making biodiesel (Zawadzki et al. 2007). Completeness of the transesterification reaction is an important quality of biodiesel.

During biodiesel production triglycerides are converted to diglycerides, which in turn are converted to monoglycerides, and then to glycerol. Each step produces a molecule of a methyl ester of a fatty acid. If the reaction is incomplete, then there will be some triglycerides, diglycerides and monoglycerides left in the reaction mixture. ASTM D 6751-09 limits total glycerol to 0.24% and free glycerol 0.02% in biodiesel to be used in vehicle. Free and total glycerol is one of the most important indicators of the biodiesel quality (Van Gerpen 2007).

Generally, the quality of biodiesel depends on several factors. One of them is impurities. Biodiesel impurities include methanol, glycerides, unconverted or partly converted fat, bound glycerol, free glycerol and catalyst (Van Gerpen 2007). Biodiesel can degrade in storage in two ways: oxidation and microbial contamination. Oxidation increases acidity and forms a gummy substance that then causes a concern for stability of the biodiesel. Microbial contamination can degrade the biodiesel since biodegradability is a property of biodiesel, and this requires water in storage tank, which causes housekeeping issues (McCormick 2006). Methanol can degrade some plastics and elastomers and is corrosive to metals. It can lower the flashpoint to unsafe levels, posing a fire hazard. Unconverted or partly converted fat is a form of bound glycerol, and may result in poor cold-flow properties, fuel-filter plugging, injector and in-cylinder deposits and potential engine failure. Free glycerol results in injector deposits, clogged fuel filters and can leave deposits at bottom of a fuel-storage tank. Therefore, in the biodiesel production process, glycerol comes as a co-product and thus, some free glycerol can be included in small amounts in the biodiesel (Oostdijk 2007). Several methods are known to determine it (Oostdijk 2007). The standard test method used for the quantitative determination of free and total glycerol contents in pure fatty-acid methyl esters (FAME) is American Society for Testing of Materials (ASTM) D 6584, ASTM D6584, 2000.

**Literature review of biodiesel sensors**

Armstrong (2007) described a gas-chromatographic method equipped with a flame ionization detector (FID). It is the technology recommended by both ASTM and European Union (EU) for the analysis of free and total glycerol. To determine free and total glycerol, the sample was first derivatized with a silylating agent and then injected into an open tubular GC column packed with a 5% phenylpolydimethylsiloxane. Calibration was achieved with two internal standards (butanetriol and tricaprin) and four reference materials. Mono-, di- and triglycerides were determined by comparison with mono-olein, di-olein and tri-olein, respectively. Hajek et al. (2006) introduced a new method that was based on the extraction of free glycerol into water and its subsequent determination in water solution by high-performance liquid chromatography (HPLC) with refractometric detection. They compared the GC and HPLC methods of free glycerol determination in biodiesel and obtained the same results, concluding that the new method was reliable and comparatively fast for free-glycerol determination in biodiesel.

Oostdijk (2007) demonstrated the suitability of an
on-column injector and the Select Biodiesel for Glycerides UltiMetal column used with Varian’s CP-3800 GC for the analysis of biodiesel. The calibration curves and repeatability data demonstrated excellent system integrity that makes the system ideally suited for the analysis of free, bound and total glycerol and mono-, di- and triglyceride content in biodiesel in accordance with the method ASTM D 6584. All samples analyzed were within standard specifications as stated in ASTM D 6751 with respect to the maximum level of free glycerol and total glycerol, except the in-house prepared biodiesel of low quality, which was as expected. However, because of the noted low levels of both glycerol and triglycerides, one sample (3S) was spiked with glycerol and triglycerides so an assessment could be made about the column’s separation performance for those components. The new Select Biodiesel for Glycerides column was able to achieve a good resolution of the biodiesel sample and was a robust solution for the high-temperature application.

Alhadeff et al. (2007) designed differential integrated systems with a bi-enzymatic biosensor; that works with two different methods of ethanol detection: flow injection analysis (FIA) and sequential injection analysis (SIA). The developed sensor was successfully applied to the detection of ethanol extracted from gasohol mixtures, and for samples of alcoholic beverages and fermentation medium. In a recent study, Zawadzki et al. (2007) proposed and evaluated a method for biodiesel blend-level detection using ultraviolet absorption spectra. The method was based on the absorbance of diluted samples with n-heptane in the UV absorption range and was found suitable for any biodiesel feedstock and independent of the diesel fuel.

The ASTM specification requires that the total glycerol be less than 0.24% of the final biodiesel product measured using a gas-chromatographic method as described in ASTM D 6584. Since the glycerol portion of the original oil is usually about 10.5%, this level of total glycerol, corresponds to 97.7% reaction completion (Van Gerpen 2007).

Compliance of ASTM D6584 requires a trained personnel and laboratory equipment. Proposed lipase-biosensor could be a means to meet ASTM standards in the quality sensing of the biodiesel. This paper proposes using lipase-biosensor that can be used to measure free and total glycerol quickly and easily. The proposed biosensor is capable of detecting and determining the quantity of glycerides (neutral fat) in the final biodiesel product and can be used as a mean of biodiesel-quality sensing.

**Proposed design of a potentiometric electrochemical lipase biosensor for biodiesel-quality sensing**

Potentiometric biosensors make use of ion-selective electrodes in order to transduce the biological reaction into an electrical signal. The simplest biosensor (Fig. 3) consists of an immobilized enzyme membrane surrounding the probe from a pH meter, where the catalyzed reaction generates or absorbs hydrogen ions. The reaction occurring next to the thin sensing glass membrane causes a change in pH that may be read directly from the pH meter's display. Typical of the use of such electrodes is that the electrical potential is determined at very high impedance, allowing effectively zero current flow and causing no interference with the reaction (Chaplin 2004).

![Figure 3](https://example.com/figure3.png)

**Figure 3.** A generalized potentiometric biosensor. An active glass membrane (A) is surrounded by a biocatalyst (B), which is contained in place by a semi-permeable membrane (C). The electric potential (e−) is generated between the internal electrode, which is suspended in dilute HCl (D), and the external pH electrode.

The following equation describes the theory behind the proposed potentiometric biosensor principle. The fundamental of the proposed biosensor operation are simple. The response of an ion-selective electrode is given by Chaplin (2004);

\[
E = E_0 + \frac{(RT)}{zF} \ln [i]
\]
where $E$ is the measured potential (in volts), $E_0$ is a characteristic constant for the ion-selective/external electrode system, $R$ is the gas constant, $T$ is the absolute temperature ($°K$), $z$ is the signed ionic charge; either positive or negative, $F$ is the Faraday constant and $[i]$ is the concentration of the free uncomplexed ionic species. Strictly, $[i]$ should be the activity of the ion but at the concentrations normally encountered in biosensors, this is effectively equal to the concentration.

Following is the lipase catalyzed reactions (Chaplin 2004) involving the release or absorption of $H^+$ ions that may be utilized by the proposed potentiometric lipase-biosensor.

\[
\text{Lipase} \\
\text{Glycerides in biodiesel} + H_2O \rightarrow \text{Glycerol} + \text{Fatty-acids} + H^+ \\
\]

The proposed lipase-biosensor (Fig. 4) is a combination of two ideas: first, is a lipase electrode where lipase will act as a biological reporter (of any biological substance that can attach itself to a particular analyte) and second, an electrode to quantify the glycerides present as impurities in the final biodiesel products. The procedure for the construction of a lipase electrode and immobilization of lipase onto the glass electrode by means of a gelatin membrane for the glass-electrode-based lipase biosensor was described by Huang et al. (2001).

The immobilization of lipase on the biosensor electrode is the key to the development of the biosensor. Immobilization of enzymes is necessary to ensure maximal contact and response, reusability of the enzyme electrode, guarantee of the enzyme stability, and less susceptibility to interference (Chaplin 2004). An important feature for the proposed biosensor is the employment of membrane technology in order to eliminate interference by other electro-active substances. This will be accomplished in the proposed biosensor with an immobilized enzyme layer in a gelatin membrane (Biosensors web book 2008). Once fabricated, the membranes have shelf lives exceeding six months (Huang et al. 2001) and are in operation two to three weeks depending upon the uses. The detector uses glass pH electrodes for $H^+$ cations (e.g. normal pH electrodes) in which the sensing element is a very thin hydrated glass membrane that generates a transverse electrical potential due to the concentration-dependent competition between the cations for specific binding sites. The selectivity of this membrane is determined via the composition of the glass (Huang et al. 2001).

The phenomenon of lipase-catalyzed hydrolysis reactions of glycerides causes a change in the pH of the solution (Reddy et al. 2001) and can be used to detect changes in pH during the hydrolysis as a shift in the capacitance-voltage (C–V) characteristics. The principle of the biosensor is based on the measurement of pH variation, which can be measured in millivolts, due to the enzymatic hydrolysis of the long-chain triglycerides (TAG) at the biodiesel-water interface, resulting in the formation of fatty acids. The procedure for the potential measurement of the lipase electrode was reported (Huang et al. 2001) as follows: potential measurements can be made at $37 \pm 0.1°C$ on a pH-3C pH / mV meter using the lipase electrode as an indicator (connected to the negative pole), a calomel electrode as reference (connected to the positive pole) and a Tris-HCl buffer ($pH = 8.5$) as medium (Huang et al. 2001). After the attainment of a steady-state potential response to the blank, biodiesel emulsion needs to be added quickly. Ten minutes later, the potential is recorded. Between measurements, the lipase electrode is rinsed with distilled water and kept in the buffer (Huang et al. 2001). The relationship between pH change and substrate biodiesel concentration is complex, including other such non-linear effects as pH-activity variation and protein buffering. However, there is a linear relationship between the apparent change in pH and the substrate concentration (Chaplin 2004, Kartal et al. 2007).
Concluding remarks

Though there are many non-health application areas for biosensors, there are still gaps between research and commercial market of biosensors. These are barriers for wide non-health applications. If the non-health areas improve and flourish, the markets and real-life biosensors application areas will increase a thousand fold. Therefore, the study of non-health application areas such as biosensor applications in biological sciences and engineering is significant. Based on a review of the literature, we have detailed a potential design for a potentiometric electrochemical biosensor system for quality sensing of potential impurities of biodiesel. The benefits of the proposed biodiesel biosensor should be as follows: it is reagentless, and can detect the biodiesel impurities such as glycerol quickly with high accuracy, sensitivity and specificity. To develop a successful biodiesel biosensor, collective effort in both multidisciplinary areas and technologies is necessary. Over time, better-designed tools, improved and standardized biosensor technologies will allow numerous biodiesel biosensor products to be economically feasible.

Literature Cited


McCormick RL. 2006. Facts about biodiesel, Power point presentations, National Renewable Energy Laboratory, Phoenix, Arizona, USA.


A Cargo of Birds to Arkansas, the Hurricanes in 2008 and the Swept Clean Hypothesis

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Abstract

Three hurricanes in the hurricane season of 2008 brought to Arkansas several unusual marine and other birds from southerly locations. There were 10 species noted, totaling 44 individual birds. Sooty Terns, numbering 15, were the most numerous. Laughing Gulls were next in abundance. In the mix of birds there was only 1 new species for the state, a Least Grebe. The hurricanes brought vastly different cargos of birds, and two hypotheses relating to how hurricanes transport birds are proposed. The findings supported the "swept clean" hypothesis over the "blown through" hypothesis.

Introduction

Hurricanes making landfall on the northern coast of the Gulf of Mexico often displace oceanic birds to unexpected locations in the interior of the USA. This phenomenon has happened in the past in Arkansas with respect to several of these species: Magnificent Frigatebird (\textit{Fregata magnificens}), Laughing Gull (\textit{Larus atricilla}), Bridled Tern (\textit{Onychoprion anaethetus}), Sooty Tern (\textit{Onychoprion fuscata}), and Black Skimmer (\textit{Rynchops niger}) (James and Neal 1986). Other descriptions of marine birds displaced by hurricanes have been published especially pertaining to the east coast of North America (Tuck 1968, Davis et al. 2004, Davis et al 2007), but also with respect to the interior in Kentucky, Tennessee, and Oklahoma (Sloan and Palmer-Ball 2005, Heck and Arbour 2010).

The hurricane season in the late summer and early fall of 2008 produced an unprecedented event of this kind in Arkansas in terms of high numbers of extralimital species found and high numbers of displaced individual birds encountered. These sightings were quickly posted by bird watching enthusiasts on ARBIRD-L, which is a web based list serve dedicated to the discussion of Arkansas birds. Material for this work was gleaned from ARBIRD-L.

In the text that follows, individual bird sightings are sometimes followed by Form numbers. These are designations that refer to the numbering system used in identifying documentation forms describing bird sightings that are submitted to the Curator of the Bird Records for the Arkansas Audubon Society. The records in 2008 described here, plus the previous records since 1985 are listed on the web site of the Arkansas Audubon Society (AAS 2010). Photographs mentioned in this manuscript are archived by the Curator.

The Hurricanes

There were 3 hurricanes of note in 2008 that made landfall on the Gulf Coast south of Arkansas and, in progressing inland, either impacted the state weather wise and/or brought unusual birds. These hurricanes were named Dolly, Gustav, and Ike. The main characteristics of the 3 hurricanes are summarized in Table 1. When hurricanes accomplish landfall south of Arkansas on the Louisiana and eastern Texas coasts the characteristic strong counter clockwise winds that circle the center of these storms would send a forceful stream of air directly northward toward Arkansas. This trajectory is capable of transporting birds to the north to Arkansas even when the storm center misses the state.

Dolly—Hurricane Dolly, the weakest of the 3, entered the Gulf of Mexico on 22 July after crossing the northeastern tip of Yucatan Peninsula. From there it journeyed across the western Gulf to reach southern Texas as a category 1 hurricane accompanied by 137 km/hr (86 mph) winds. It made landfall on 24 July 2008 in the vicinity of South Padre Island on the Texas-Mexico boundary (Pasch and Kimberlain 2009). From there it coursed inland to the northwest, through northern Mexico, then northward across New Mexico and dissipated at the tip of the Oklahoma panhandle. It did not come close to Arkansas, yet it seemingly delivered a new avian species to the state (see below).

Gustav—Hurricane Gustav arrived from the Caribbean south of Cuba and entered the Gulf after crossing the western tip of Cuba. It was a category 2 hurricane with 167 km/hr (104 mph) winds when it
Table 1. Characteristics of the three hurricanes in 2008 and species and numbers of unusual birds transported to Arkansas.

<table>
<thead>
<tr>
<th>Hurricanes</th>
<th>Dolly</th>
<th>Gustav</th>
<th>Ike</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landfall date (2008)</td>
<td>22 July</td>
<td>1 Sept</td>
<td>13 Sept</td>
</tr>
<tr>
<td>Landfall region</td>
<td>TX-Mexico</td>
<td>SE LA</td>
<td>SE TX</td>
</tr>
<tr>
<td>Landfall wind speed—km/hr (mph)</td>
<td>137 (86)</td>
<td>167 (104)</td>
<td>175 (109)</td>
</tr>
<tr>
<td>Crossed Arkansas</td>
<td>n/a</td>
<td>3&amp;4 Sept</td>
<td>14 Sept</td>
</tr>
<tr>
<td>Arkansas wind speed—km/hr (mph)</td>
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<td>37 (23)</td>
<td>50 (31)</td>
</tr>
<tr>
<td>Arkansas wind gusts—km/hr (mph)</td>
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<td>90 (56)</td>
</tr>
<tr>
<td>Birds counted:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Least Grebe</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Magnificent Frigatebird</td>
<td>0</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Laughing Gull</td>
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<td>14</td>
<td>0</td>
</tr>
<tr>
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<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Bridled Tern</td>
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<td>1</td>
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<tr>
<td>Sooty Tern</td>
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<td>Pomarine Jaeger</td>
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</tr>
<tr>
<td>Parasitic Jaeger</td>
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</tr>
<tr>
<td>Cave Swallow</td>
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<td>0</td>
</tr>
<tr>
<td>Total birds counted</td>
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<td>41</td>
<td>2</td>
</tr>
</tbody>
</table>

made landfall on 1 September 2008 on southeastern coastal Louisiana coursing inland to northwestern Louisiana and southwestern Arkansas (Beven and Kimberlain 2009). From there it journeyed northward through western Arkansas and then across the northwestern part of the state into Missouri. Gustav crossed Arkansas on 3 and 4 September 2008, producing sustained winds of 37 km/hr (23 mph), gusting to 77 km/hr (48 mph). On 5 September its center was over central Illinois.

Ike—Arriving from the Atlantic, Hurricane Ike, the strongest of the 3, missed the Caribbean instead raked much of Cuba, then coursed over open water to southeastern Texas. It was a category 2 hurricane with 175 km/hr (109 mph) winds when on 13 September 2008 it made landfall on Galveston Island in southeastern Texas (Berg 2009). Inland from there it went very rapidly north through eastern Texas to southwestern Arkansas and then to northwestern Arkansas and into Missouri. Ike crossed Arkansas on 14 September 2008 with sustained winds of 50 km/hr (31 mph), gusting to 90 km/hr (56 mph). A day later on the 15th its center was over Lake Huron, Ontario, Canada.

In the Atlantic Ike's diameter was the widest tropical storm ever recorded. It became the worst hurricane ever in Texas and scored high on several measures of force and destruction. It produced flooding and damage through the Midwestern states producing 129 km/hr (80 mph) winds up the Ohio River Valley (Lehman and Brinkley 2009).

Results

There were 10 avian species totaling 44 birds reported in Arkansas that normally are found in association with the Gulf of Mexico and are unusual in Arkansas, including 1 new species for the state. Below are the main species that appeared in the state coincident with coastal hurricane events in 2008. The avian information is summarized in Table 1.

Least Grebe (Tachybatus dominicus)—This species, a new bird for Arkansas (James et al. 2009), was discovered at the State Fish Hatchery at Centerton,
Benton Co., on 2 August 2008 (Form 1004 and photograph). This date was ten days after Hurricane Dolly landed from the Gulf at the Texas-Mexico boundary in the vicinity of South Padre Island. Although the inland track of Dolly went far to the west of Arkansas, the coastal region impacted by Dolly is a well documented nesting area for the freshwater Least Grebe, which extends as far north as southern Texas (Storer 1992). There have been scattered records further northward in recent years (Anonymous. 2008). The strong winds that blew through northwestern Arkansas on the night of 30-31 July (D. James, personal observation) could have moved the grebe to Arkansas after first being blown inland by Hurricane Dolly. The fierce counterclockwise winds associated with hurricanes, described above, initially would have sent the grebe toward Arkansas.

The Least Grebe was the only species noted that could have been displaced to Arkansas after Hurricane Dolly. Of the remaining 9 species that are accidental in Arkansas, all were associated with the passage of Hurricane Gustav and only 2 individual birds of the 9 appeared with Ike.

**Magnificent Frigatebird (Fregata magnificens)**—This is an extralimital species that arrived in Arkansas on the winds of Hurricane Gustav. There were three sightings on 2 September, at the following locations: Grand Lake in Chicot Co. White Oak Lake in Ouachita Co. (Form 1027 and photograph), and Lake Millwood in Hempstead/Little River cos. The one at Lake Millwood was joined by a second bird on 3 September thus totaling 4 birds for the season. There were 11 previous Arkansas records, often associated with coastal hurricanes (James 1964, James and Neal 1986, James et al. 1994, 2007). The species nests throughout the Caribbean and at a few locations in the southern Gulf of Mexico (Diamond and Schreiber 2002).

**Laughing Gull (Larus atricilla)**—There are many past records of this gull in Arkansas, often after hurricanes (James and Neal 1986, AAS 2010). This is consistent with its pattern of wandering north of its normal range on the northern Gulf Coast (Burger 1996). Considering its normal range, it is a prime candidate for being transported northward by hurricanes. Significant in this regard were the 12 birds seen on 2-7 September at Lake Millwood, (photograph), 2 at Lake Dardanelle, Yell/Pope cos., on 4-6 September, associated with the winds of Hurricane Gustav crossing Arkansas. Because almost all previous sightings of Laughing Gulls in Arkansas were of scattered single birds, the relatively high numbers found in early September 2008 implicates a massive transport of birds from the Gulf shores by Gustav. Totaling 14 birds, it was the most numerous Gulf shoreline species found in Arkansas during the hurricane season in 2008.

**Royal Tern (Sterna maxima)**—The Royal Tern is another species that normally is confined to coastal areas, but can range from the Gulf Coast to the eastern coast of North America, and is known to journey inland especially after tropical storms (Buckley and Buckley 2002). Two arrived with the aftermath of Gustav winds, 1 at White Oak Lake on 2 September, the other at the State Fish Hatchery at Centerton on 4 September. Another one was found at Lake Millwood, Little River Co., on 16 September, which means it probably was transported by Hurricane Ike. There were previously only 5 reports of Royal Terns in Arkansas (James et al. 1994, 2007, AAS 2010).

**Bridled Tern (Onychoprion anaethetus)**—This tern is another oceanic bird that seldom ventures into the interior of North America (Haney et al. 1999). One was observed on Lake Millwood on 3 September carried by Gustav winds (Form 1021 plus photograph). This is only the second record for Arkansas. The previous one, also found at Lake Millwood, was observed on 7 September 1985 in association with Hurricane Elena (James and Neal 1986).

**Sooty Tern (Onychoprion fuscata)**—By far the greatest influx of marine birds associated with Gustav was exhibited by the sightings of 15 Sooty Terns at wide ranging locations in Arkansas, as follows listed by date: 2 on 2 September at Lake Chicot, Chicot Co., and 1 at White Oak Lake; on 2-7 September, up to 9 at Millwood Lake, and 2 at Lake Dardanelle; on 6 September 2008, 1 at Beaver Lake, Benton Co (Forms 999, 1024, 1025 plus photograph). One was found dead in emaciated condition at Lake Dardanelle by R. Wiedenmann on 8 September (specimen now in the Museum of Natural Science Cat. No. LSUMZ 181469 at Louisiana State University.) There are only 3 previous records of Sooty Terns in Arkansas, all hurricane related (James and Neal 1986, AAS 2010). Sooty Terns are essentially a Caribbean bird (Schreiber et al 2002).

**Black Skimmer (Rynchops niger)**—Three Black Skimmers, a Gulf shoreline bird (Cochfeld and Burger 1994), were observed in Arkansas associated with the hurricane-generated winds in 2008 passing through Arkansas. Two were found with respect to Gustav: an adult bird on 6 September and an immature on 7 September, both at Lake Millwood (Form 1026 and photograph). Another bird was found on 14 September, a date that coincides with the arrival of
winds from Hurricane Ike in the state. This skimmer was discovered on the Arkansas River, 2 miles south of the David D. Terry Lock and Dam, Pulaski Co. Previously there were 5 skimmer records in Arkansas (James and Neal 1986, AAS 2010).

There were 3 other species observed with the hurricanes in 2008 that could have been moved to Arkansas. However, these birds are not regularly associated with hurricane winds through the state, and although they are uncommon in occurrence, they are more regular in occurrence than the species named above.

Over the years, 2 fall migrants have been noted at Lake Millwood that nest in the Arctic and are headed to the Gulf of Mexico. Single observations of each species were made there again in the regular fall season of migration in 2008, but this time when Gustav impacted Arkansas. This suggests that they could have been brought from the Gulf on the winds of Hurricane Gustav. The rarest was one Pomarine Jaeger (Stercorarius pomarinus), (Form 1023 plus photo) which was only the third record for the state (James and Neal 1986, AAS 2010). One Parasitic Jaeger (Stercorarius parasiticus) (Form 1022), was at least the eighth Arkansas record (James and Neal 1986, AAS 2010). Both of these were found on 6-7 September.

Cave Swallow (Hirundo fulva) The breeding range of this swallow has been expanding northward in Texas and now has reached the northeastern part of the state (Koscuich et al. 2006). Recently juvenile birds and an adult have been found in spring in Arkansas (AAS 2010). One was found at Lake Millwood on 2 September 2008, possibly transported by Gustav. It was the fourth record for Arkansas.

Discussion

Three hurricanes, Dolly, Gustav, and Ike, brought unusual birds from the Gulf of Mexico and its environs to Arkansas in the hurricane season of 2008. Six species were either oceanic birds or marine shoreline inhabitants, and 2 were fall migrants possibly blown in a reverse direction. One was a bird whose northern distribution ends in southern Texas, and 1 was a bird that normally nests north to central Texas. All 10 species combined, there were 44 individual birds involved, 41 of which were associated with Hurricane Gustav, but only 1 bird arrived after Dolly and only 2 with Ike. Fifteen Sooty Terns were the most abundant, followed in numbers by the 14 Laughing Gulls.

The minimal effect of Dolly is understandable due to its relative weakness and also the fact that it missed Arkansas. However, both Gustav and Ike were strong hurricanes and both crossed Arkansas, yet Gustav was responsible for 41 displaced birds while Ike produced only 2. Ike arrived quickly after Gustav, they were less than two weeks apart, and made landfall on essentially the same part of the Gulf coast. Perhaps the Gulf birds that were in position and therefore exposed to being transported were all removed northward by Gustav and none remained when Ike arrived shortly thereafter. This possible phenomenon could be called the "swept clean" hypothesis.

Another hypothesis pertains to the speed at which Ike went inland compared to Gustav. Gustav took two days to cross Arkansas and next day had moved only as far as Illinois. The faster moving Ike exhibited stronger winds than Gustav. It crossed Arkansas in a single day and by the next day was over Lake Huron in Canada. The opportunity to deploy its avian cargo may have been greater with slowly moving Gustav compared to rapidly moving Ike, whose high velocity strong winds could have held its displaced birds until reaching far northern localities. This possibility could be named the "blown through" hypothesis.

A test of these two hypotheses is present in the list of storm birds found in the Central Southern and Midwestern States in association with the hurricanes. The first storm Gustav brought significant numbers of hurricane birds to Arkansas, Louisiana, and Oklahoma, but even with continued heavy coverage by avian observers in states to the north plus Ontario virtually none of the storm birds were found (Lehman and Brinkley 2009). Because Gustav stalled and weakened in Arkansas taking two days to cross the state, the subsiding winds were not capable of producing a "blown through" event.

Ike was wholly different, following Gustav by less than two weeks, it maintained strong winds into the Midwestern states, crossed Arkansas in just one day and was in Ontario, Canada, the next day. Ike brought a few hurricane birds to Louisiana, especially Sooty Terns, but it was noted that Gustav produced the "greatest variety of inland pelagic birds" there (Cardiff 2009). Ike brought almost no storm birds to Arkansas (Cardiff 2009), and as with Gustav were absolutely not detected in states to the north despite extensive coverage by observers there (Lehman and Brinkley 2009). Ike certainly qualified for a "blown through" event but because no storm birds materialized in northern regions this possibility is rejected. The fact that Louisiana received relatively fewer birds and Arkansas received only two hurricane birds with Ike shortly following Gustav supports the "swept clean"
hypothesis, which suggests that few ocean and coastal birds were left by Gustav to be transported by Ike. 

Heck and Arbour (2010) described the birds brought with hurricanes Gustav and Ike to southeastern Oklahoma. Their results are similar to those in Arkansas, reporting many of the same species named in the present paper plus a possible Cory’s Shearwater (Calonectris diomedia). Most of the 36 birds observed were associated with Gustav, only 4 with Ike.

Similar support for the “swept clean” hypothesis occurred in 2005 when first hurricane Katrina made landfall at the Louisiana-Mississippi boundary on 29 August followed less than a month later by Rita landing in the same region at the Texas-Louisiana border on 24 September. Katrina transported inland “an assortment of grounded seabirds and coastal birds the likes of which had never been observed after a Gulf hurricane,” whereas with respect to seabirds carried by the later arriving Rita ”only a few were reported” (Dinsmore 2006). Apparently Katrina “swept clean” most the available seabirds leaving few for Rita. Therefore, based on the hurricane events described herein, it seems the “swept clean” hypothesis is supported in which the first of two closely following hurricanes removes almost all birds that are in a position to be transported inland leaving few for the one that follows. The dead emaciated Sooty Tern found in Arkansas portends the fate of the transported birds. They indeed may not survive to return to their marine environment.

The Magnificent Frigatebird is a special case. This bird is superbly designed for sailing with the wind and it does. All four hurricanes detailed here transported frigatebirds in significant numbers inland to widely distributed locations even into the northern states (Dinsmore 2006, Duncan and Duncan 2006, Cardiff 2009, Lehman and Brinkley 2009). Cardiff reports hundreds brought by Ike occurring in southern Louisiana and adjacent Texas. Frigatebirds definitely are easily blown and sail everywhere with the wind.

(We note in the Fall Migration, August to November 2008, issue of North American Birds that the numbers of storm birds reported for Arkansas differ from the numbers reported herein. Our figures were obtained from the official records maintained by the Curator of bird records for the Arkansas Audubon Society that were posted on ARBIRD-L).

Acknowledgments

One of the authors of this paper found a Royal Tern, two authors saw the Least Grebe. So we gratefully acknowledge the cadre of energetic expert bird watchers in Arkansas for finding the birds that made this publication possible. Therefore we thank for their efforts: Leif Anderson, Dick and Sarah Baxter, Dennis and Patricia Braddy, Jacque Brown, Kelly Chitwood, Hilda Jones, Guy and Scott Luneau, Charles Mills, Mike Modinow, Kenny and LaDonna Nichols, Dan and Samantha Scheiman, Robert Wiedenmann, Don Simons, and Lyndal York.

Literature Cited


A Cargo of Birds to Arkansas, the Hurricanes in 2008 and the Swept Clean Hypothesis


Tuck LM. 1968. Laughing Gulls (Larus atricilla) and Black Skimmers (Rynchops nigra) brought to Newfoundland by hurricane. Bird-Banding 39: 200-8.
Comparative Leaf Decomposition Rates Including a Non-Native Species in an Urban Ozark Stream

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Abstract

Leaf decomposition of three species of native Ozark vegetation was compared to that of one non-native invasive species. Leaves were placed in an urban gravel-bed stream for 23 days. Changes in mass and condition of the leaves were assessed along with stream temperature, flow, width, depth and discharge. Species native to Eastern North American forests were sycamore (Platanus occidentalis), dogwood (Cornus florida), and redbud (Cercis canadensis). The non-native species, Japanese (Amur) honeysuckle (Lonicera maackii) comprised approximately 80% of the understory vegetation within the riparian zone of the study reach. After 23 days, Sycamore lost 24.6% mass, dogwood lost 30%, redbud lost 37.5%, and honeysuckle lost 38.3%. Sycamore leaves retained their relative structures the most (ranked 9 on a scale of 1 to 10, with 10 being the most sclerophyllous), and honeysuckle the least (ranked 2 on a scale of 1 to 10). As a result of this study, we suggest that the fast decomposition of leaves at southern latitudes may contribute to the low percentage of detritivores in streams, and that Japanese honeysuckle exacerbates this situation as a result of its more rapid rate of decomposition, therefore potentially depriving univoltine detritivores of nutrients later in their life cycles.

Introduction

Comparative leaf decomposition rates in streams among latitudes, stream types, ecoregions, disturbed/non-disturbed regions, and urban versus rural areas are of considerable interest due to the influence of decomposing leaves on stream community structure and function (Cummins 1974, Allan 1995, Tank et al. 2010). Leaf decomposition and processing rates are largely determined by the leaf species that accumulate in packs in the streams (Petersen and Cummins 1974, Tank et al. 2010). The different taxa of plants vary in toughness (sclerophyllus) due to amounts and types of secondary chemical compounds (e.g., lignin, suberin, and cellulose) that make living plants able to more effectively resist decomposers and herbivores and therefore remain available in the stream for long periods of time (Turner 1994, Woodcock and Huryn 2005, Read and Sanson 2003). These differences in physical and chemical attributes are present in abscised leaves and slow their consumption by detritivores (Swan and Palmer 2006). Other secondary compounds that are part of a living plant’s defense system have a chemical rather than physical mechanism of resistance (phenolics, tannins, irritants, allergens). However, these compounds are mostly water soluble and are removed by dissolution, so are less of a deterrent to aquatic detritivores (Hoorens et al. 2010).

Processing (colonization by microbes) is essential to enhancing the nutrient content of autumn-shed leaves (Petersen and Cummins 1974, Findlay 2010). Fallen leaves may vary in amount of nutrient content (nitrogen, phosphorus, and micronutrient compounds), and therefore differ in palatability to invertebrate consumers (Read and Sanson 2003, Pérez-Suárez et al. 2009). Sequestration of nutrients is common among plants that periodically shed their leaves (Horton and Brown 1991), so nutrients are reduced in all naturally abscised leaves. However, leaves and leaf parts (including frass) that enter streams as a result of insect activity in canopy trees, wind, and/or hail storms prior to abscission are more nutritious and are consumed faster by stream invertebrates (Horton and Brown 1991, Pérez-Suárez et al. 2009).

Decomposing leaves fuel most woodland stream communities and as the base of the food web are very important to community structure and function (Petersen and Cummins 1974, Swan and Palmer 2006, Pérez-Suárez et al. 2009, Hoorens et al. 2010). The community structure and function in Ozark streams is unique in that Nearctic fish species assemblages lack native detritivores and herbivores (Brown and Matthews 1995). As a result, consumption of decomposing leaves in Nearctic streams is primarily done by invertebrate detritivores. Shredding
Invertebrates, like any animals, need a good supply of nutritious food during their entire lives to live and grow, and if they exhaust supplies, must cease growing and perhaps die (Cummins 1974, Swan and Palmer 2006). In most northern temperate streams the leaves take a year or more to decompose or disappear (Peterson and Cummins 1974) allowing univoltine obligate detritivores to have some food available throughout their life cycles (Cummins 1974). The higher temperatures found in Ozark streams, on the other hand, result in faster decomposition rates thus causing faster depletion of allochthonous litterfall (Tank et al. 2010). Hydrological conditions that produce spiky hydrographs like those recorded in Ozark streams exacerbate the situation by transporting leaves from streambeds to the floodplains (Brown and Matthews 1995). The limited duration of leaf material in southern streams may partially explain the limited number, diversity, and biomass of detritivores (particularly shredders) (Brussock and Brown 1991, Brown and Matthews 1995, Brown et al. 2005).

Non-native invasive plants like the Japanese (Amur) Honeysuckle (*L. maackii*) have the potential to further alter the balance of detritus/detritivores in some southern streams where Japanese honeysuckle is becoming abundant in riparian forests (O’Connor et al. 2000, Collier et al. 2002, USDA 2010). Japanese honeysuckle is a large woody shrub that prefers open understory sites, especially in riparian areas (Collier et al. 2002, USDA 2010). Disturbances to natural forest communities make the forests vulnerable to colonization by this and other invasive plants (Collier et al. 2000). Dispersal of honeysuckle seeds by birds is common and it also spreads by sprouting from lateral growths of roots (Deering and Vankat 1999). This species is of concern as an aggressive invasive plant in at least 11 southeastern states including Arkansas (NRCS 2010, USDA 2010). Washington County, the location of this study, is among three counties in Arkansas that have been recognized by the Natural Resources Conservation Service and the United States Department of Agriculture as particularly vulnerable to infestation by this species (NRCS 2010, USDA 2010).

The objectives of this study were to 1) compare leaf decomposition of *L. maackii* to that of three species of flora native to Eastern North American forests and 2) to relate the decomposition rate of *L. maackii* to its potential impacts on nutrient availability for detritivores. The null hypothesis was that no significant difference would exist between the decomposition of *L. maackii* and that of the three native Eastern North American species, therefore having little or no effect on nutrient availability in the watershed and therefore having no impacts on detritivore assemblages.

**Materials and Methods**

**Study area**

This study was performed on Mud Creek, a second order stream in Fayetteville, Arkansas, which is a tributary of Clear Creek in the headwaters of the Illinois River watershed (36° 06’ 55.6” N and 94° 07’ 55.8” W). The Mud Creek watershed covers 43.49km² and land uses are predominantly urban (59.3%), forest (20.42%) and pasture (14.05%) (CAST 2006). The 29m reach used for the study was located alongside a suburban hiking trail and had at least 10m of riparian forest along both banks. The canopy cover consisted of deciduous trees including sycamore (*Platanus occidentalis*), oak (*Quercus spp.*), dogwood (*Cornus florida*), ash (*Fraxinus spp.*), redbud (*Cercis canadensis*), and maple (*Acer spp.*). *L. maackii* was prevalent along the stream segment and occupied approximately 80% of the riparian understory based on visual estimates. The stream had been heavily eroded as a result of channeling and bank alterations. Although it retained some riffle, pool, and flat habitats which are characteristic of gravel bed streams (Brussock and Brown 1991), substrate consisted of mostly bedrock and boulders with little gravel bedload remaining.

**Leaf preparation and analysis**

Four different species of leaves were compared in this experiment, three native species and one non-native species, respectively; 1) dogwood, 2) redbud, 3) sycamore, and 4) honeysuckle. Three leaf packs (three 4g leaf packs in 7 mm mesh) were prepared for each species from air-dried leaves that were harvested from trees in the study area just prior to natural abscission (Petersen and Cummins 1974, Wallace et al. 1982, Li et al. 2009). The leaf packs (12 in total) were secured with string to boulders along the side of the stream opposite the hiking path to discourage tampering. The leaf packs were placed by groups of four (one of each of the species) in three locations along the left bank where natural leaf accumulations existed and in areas of similar flow and depth. All of the leaf packs were removed after 23 days (6 October until 11 November). At that time, each pack was placed in individual plastic bags with watertight closure mechanisms and immediately returned to the lab where they were gently washed of sediment. Associated invertebrates were
collected separately from each leaf pack and fixed in 70% alcohol for subsequent identification and counting. The leaves were air-dried and then weighed to assess loss of mass. Leaves were also qualitatively ranked on a scale of 1 to 10 to assess relative change in sclerophyll. This scale was based on relative comparisons between species after submersion in the stream. A score of “10” indicated the highest level of sclerophyll or no change in toughness. A score of “1” indicated very low sclerophyll wherein the leaf easily disintegrated upon handling after being submerged. Percent loss over time was calculated to establish rate of decomposition over 23 days and was calculated based on the methodology used by Petersen and Cummins (1974). We simultaneously measured physical and chemical conditions of the study stream to make the results more comparable with other studies. Invertebrates from the experimental leaf packs were assessed to determine the presence of detritivores.

Changes in the mass and structural integrity for each species were statistically compared through one-way ANOVA and Student’s t-test analyses (α=0.05) (Maciá and Bradshaw 2000). Statistical analyses were conducted using JMP software.

Table 1. ANOVA and t-test analyses of mass loss and structural ranking of four species of leaves after 23 days in an Ozark stream. Species with different letter (A, B) associations are statistically different. Loss/day and % loss (%R) indicate the rate of decomposition over 23 days.

<table>
<thead>
<tr>
<th>Plant name</th>
<th>Student’s t-test Statistical Association</th>
<th>Mean change in mass (g)</th>
<th>Mass loss/day (g)</th>
<th>% Loss</th>
<th>Mean condition (sclerophylly) ranking (scale 1-10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Honeysuckle (L. maackii)</td>
<td>A</td>
<td>1.58</td>
<td>0.07</td>
<td>38.30</td>
<td>2.00</td>
</tr>
<tr>
<td>Redbud (C. 94anadensis)</td>
<td>A</td>
<td>1.55</td>
<td>0.07</td>
<td>37.50</td>
<td>4.00</td>
</tr>
<tr>
<td>Dogwood (C. florida)</td>
<td>B</td>
<td>1.24</td>
<td>0.05</td>
<td>30.00</td>
<td>7.33</td>
</tr>
<tr>
<td>Sycamore (P. occidentalis)</td>
<td>B</td>
<td>1.00</td>
<td>0.04</td>
<td>24.60</td>
<td>9.00</td>
</tr>
<tr>
<td>p value</td>
<td></td>
<td>0.0040</td>
<td>0.0044</td>
<td>0.0055</td>
<td>0.0020</td>
</tr>
<tr>
<td>Standard error</td>
<td></td>
<td>0.0872</td>
<td>0.0038</td>
<td>2.1382</td>
<td>0.8819</td>
</tr>
</tbody>
</table>

Discussion and Conclusion

These results suggest that leaves of Japanese honeysuckle are among the fastest to decompose in an Ozark stream (Petty and Brown 1982, Brussock et al. 1988, Horton and Brown 1991, Li et al. 2009). Changes within southeastern riparian forests, such as those caused by invasive species like Japanese honeysuckle (Collier et al. 2001), have the potential to affect nutrient availability within stream ecosystems as a result of their rate of decomposition (Cornelissen and Thompson 1997, Rosemond et al. 2010). We observed, therefore, that since the honeysuckle plants decomposed rapidly and were found beside and overhanging the stream, they may affect detritivore population and nutrient availability within the stream. Although sycamore and dogwood were slower to decompose than the other two species, they would not be classified as slow by most investigators because leaf decomposition is rather fast at this southern latitude due to higher temperatures (Brown...
Comparative Leaf Decomposition Rates Including a Non-Native Species in an Urban Ozark Stream

and Matthews 1995).

Diverse leaf packs provide nutrition over a longer period of time because leaves become or remain palatable at different times based on species-specific chemistry and tissue structure. This determines the amount of time detritivorous invertebrates have to take advantage of the decomposing allochthonous detritus. Generally, detritivores (especially shredders) are univoltine requiring long periods of growth to complete their life cycles. We suggest that the rapid decomposition of leaves at southern latitudes may contribute to the low percentage of shredders in Ozark streams and that Japanese honeysuckle exacerbates this as a result of its invasive characteristics and its rapid rate of decomposition.

We propose two potential effects that Japanese (Amur) honeysuckle could have on nutrient availability in Ozark streams. First, an abundance of relatively rapidly decomposing leaves in a stream during autumn could encourage growth of shredders and possibly other detritivores. However, invertebrates with longer life histories and thus longer periods of need for detritus, could be left without suitable food resources later in their development (Maciá and Bradshaw 2000). Since Japanese honeysuckle decomposes rapidly, its leaves may not support long-lived detritivores. On the other hand (and a potential topic for future research), these plants are understory shrubs and, as a result of their “shrub-like” structure, may trap leaves which fall from taller species of trees in the riparian zone (Horton and Brown 1991). Since Japanese honeysuckle decomposes rapidly, its leaves may not support long-lived detritivores. On the other hand (and a potential topic for future research), these plants are understory shrubs and, as a result of their “shrub-like” structure, may trap leaves which fall from taller species of trees in the riparian zone (Horton and Brown 1991). We are not certain what effect this may have on the stream macroinvertebrates, if any, but suggest that the intercepted leaves may be released later and actually increase the period of time when leaves are available to stream detritivores despite their rapid rate of decomposition.

In summary, Japanese honeysuckle has the potential to affect nutrient availability by either shortening or lengthening the duration of the food supply within a stream. More research is needed to further explore the relationships. Removal of the invasive plants seems to be the correct course of action because of the potential impacts on leaf litter diversity (Cornelissen and Thompson 1997), but the overall impact of their presence on stream communities in the southeastern United States remains uncertain and more investigation is needed.

Acknowledgments

We appreciate the use of laboratory equipment and space provided by the University of Arkansas Department of Biological Sciences. The University of Arkansas Center for Advanced Spatial Technologies (CAST) graciously provided land use/land cover information for the watershed. Ferrell Killion, of the United States Geological Society, provided equipment for measuring physical properties of the stream. The City of Fayetteville, Arkansas willingly allowed access to the study site.

Literature Cited


Distribution of the Southeastern Shrew (*Sorex longirostris longirostris*) in Arkansas

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Abstract

The southeastern shrew (*Sorex longirostris longirostris*) is considered uncommon and, due to a lack of knowledge, a Species of Greatest Conservation Need in Arkansas. Also, eastern Arkansas may represent a gap in the species’ distribution. Therefore, we evaluated persistence at previous capture sites, surveyed additional counties, quantified microhabitat at our capture locations, and compiled occurrences. Since Sealander and Heidt’s (1990) *Arkansas Mammals* detailed its occurrence, additional captures by Huston and Nelson (1994), Showen (2006), and this study document new counties (Pope and Searcy) and a new ecoregion (Arkansas Valley). Number of specimens in Arkansas has increased to 17 in 11 counties within the Ozark Highlands, Boston Mountains, Ouachita Mountains, and Arkansas Valley Ecoregions. Our efforts to assess a potential distribution gap within the Mississippi Alluvial Plain produced only specimens of other shrew species; therefore, possible factors affecting connectivity across the Mississippi Alluvial Plain and river basin are discussed. Given sparse records in Arkansas, uncommon and Species of Greatest Conservation Need designations are warranted for the southeastern shrew.

Methods

From March 2007 to August 2009 we operated pitfalls, small folding aluminum (SFA) Sherman traps, large folding aluminum (LFA) Sherman traps, and snap-traps. Pitfalls (1L plastic buckets) were placed 3-7m apart in series with 15cm aluminum roof flashing as drift-fencing or set in grids, along deadfall or under low level vegetation without fencing. Sherman and snap-traps were baited with combinations of peanut butter, rolled oats, crushed dry cat food and minced sardines. Traps were checked daily. Capture and handling conformed to appropriate guidelines (Gannon and Sikes 2007, University of Arkansas at Little Rock [UALR] IACUC # R-07-04). Microhabitat variables (Dueser and Shugart Jr. 1978), including volume and decay stage (1-4) of coarse woody debris (CWD; Cromer et al. 2007), were quantified within a 10m x 10m plot centered on capture locations. Specimens were deposited in the UALR Vertebrate Museum.

Results

Capture efforts resulted in 17,983 trapnights at 329 locations with 2 captures and a new county record (*Searcy County*) for *S. l. longirostris* (Figure 1). These specimens were 2 non-lactating adult females with no embryos trapped in an SFA Sherman baited with peanut butter and dry cat food and an LFA baited with peanut butter and rolled oats. Efforts at previous capture sites (4472 [25%] trapnights) resulted in 10 *Blarina spp.*, whereas efforts in the upper Mississippi Alluvial Plain (3640 [20%] trapnights) resulted in 8 *Blarina carolinensis* and 5 *Cryototis parva.*

 Specimen UALRVC5733 (Pope County) occurred in a pecan (*Carya*)-oak (*Quercus*)-pine (*Pinus*) overstory valley with low-level blueberry (*Vaccinium*), elm (*Ulmus*), grape (*Vitis*), sweetgum (*Liquidambar*), catbrier (*Smilax*), honeysuckle (*Lonicera*), and sassafras (*Sassafras*), 35m from water. Specimen UALRVC5734 (Searcy County) occurred in an oak-hickory (*Carya*) overstory ridge with oak seedlings, 150m from water. At the 2 *S. l. longirostris* capture sites, mean CWD volume was 26984.90cm³ (13cm x 200cm log equivalent) and CWD decomposition scored 2.75 (2.5-3.0). Mean leaf litter depth was 2.55cm (2.5-2.6cm) with 97.68% (99.55-95.8%) coverage.

**Discussion**

The southeastern shrew can be found in early successional to mature second-growth forest and from dry upland hardwoods and grass fields to hardwood forests near small streams and bordering swamps, marshes, or rivers (Hamilton and Whitaker 1979, French 1980, Caldwell and Bryon 1982, Elliot and Root 2006). Foraging most often occurs under leaf
Distribution of the Southeastern Shrew (Sorex longirostris longirostris) in Arkansas

litter (French 1980) that, with intermediary decayed CWD, provides cover for S. l. longirostris and habitat for invertebrate prey. The species is also associated with a heavy ground cover of grasses, sedges, rushes, blackberry and, honeysuckle (French 1980, Webster et al. 1985). For Arkansas, previous captures are described to be in overstory maple, hickory and oak with low-level blackberry, witch-hazel, sumac, sassafras, redbud, honeysuckle and overstory species seedlings (Graham 1976, Sealander 1977, Garland and Heidt 1989). Habitat for our specimens is consistent with previous Arkansas captures, although additional captures with quantified microhabitat characteristics are necessary to suggest a preferred type in Arkansas.

Studies carried out elsewhere in their distribution have suggested that S. l. longirostris can be rare (Lowery 1974, Brown 1978). Furthermore, when allopatric, Sorex cinereus and S. l. fisheri occur in mesic lowlands and river floodplains, whereas S. l. longirostris occurs in xeric upland forests and outside floodplain boundaries (Gentry et al. 1971, French 1984, Rose et al. 1987, Parmley and Harley 1995, Ford et al. 2001). Although S. l. longirostris occurs on the upland Bluff Hills of the Mississippi Valley Loess Plains on the east side of the Mississippi River in Tennessee (Heidt et al. 1996, Tennessee Wildlife Resources Agency 2005), the west side of the river in Arkansas is the more mesic lowland Mississippi Alluvial Plain. For Arkansas, this suggests the possibility of an uncommon occurrence of S. l. longirostris in more mesic areas such as the Mississippi Alluvial Plain where we only captured B. carolinensis and C. parva.

Management that develops and maintains forest openings creating diversity of habitats and microhabitats would have a positive effect on S. l. longirostris. We suggest subsequent shrew collection efforts use a high density of traps that remain operational for as long as possible. Pitfalls without fencing, making use of naturally occurring CWD and vines, are more time-efficient and potentially more effective where fencing can not be made flush with or buried into a rocky substrate. Sherman traps, when set sensitively, can capture small shrews and should be employed. In addition, solicitations for owl roosts and captures by domestic cats should be sought. Future studies could examine this potentially disjunct population using genetic sequencing and shrewd analyses of population dynamics.

Acknowledgments

We thank the Arkansas Game and Fish Commission and the United States Fish and Wildlife Service for the State Wildlife Grant that funded this study, as well as many federal, state, and private land managers/owners for access. We also thank S.A. Baird, W.H. Baltosser, and R.S. Sikes for their contributions and 3 anonymous reviewers for comments

Literature Cited


Sealander JA. 1981. Albino least shrews (Cryptotis parva) and a new locality record for the southeastern shrew (Sorex longirostris) from Arkansas. The Southwestern Naturalist 26(1):70.


Optical Characterization of Silver Doped Poly (Vinyl Alcohol) Films

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Abstract

Silver-doped PVA films were prepared by casting method in order to study the effect of silver on the optical properties of poly(vinyl alcohol) using UV/VIS spectroscopy. It was found that these thin films have an indirect optical band gap (2.4-1.3) eV as the doping percentage increase. Extinction coefficient and refractive index increase as the doping percentage increase, while in general the optical dispersion parameters show an opposite behavior with doping.

Introduction

Polymeric materials are of interest in scientific and technological research (Mule et al. 2004, Liu et al. 2005, Chen et al. 2006) because they can be tailored to meet specific requirement for a variety of applications, this is mainly due to lightweight, good mechanical strength, optical properties (Bhajantri et al. 2006, Bulinski et al 2004).

Poly(vinyl alcohol) (PVA) is one of most important polymeric materials, because it has many applications in industry and is of relatively low cost in manufacture (El-Sherbiny et al. 2001). For instance, it can be used as a solid polymer electrolyte when doped with phosphoric acid in solid state electrochromic display (ECD), solid state photocells (Somani et al. 2000, Somani and Radhakrishnan 2001), or as a steric stabilizer for producing conducting polymer dispersion (Somani 2002).

In recent years, doped polymers have been a subject of considerable interest because their physical and chemical properties make them useful for specific applications.

In this manuscript, we examine combining the features of organic materials with those of inorganic materials in this work. The PVA solution films with different amounts of AgNO₃ dopant were prepared by solution casting method. 1 g of PVA powder was added to doubly distilled water and allowed to swell for 24 h at room temperature. Silver nitrate was dissolved in redistilled water and added to the polymeric solution with continuous stirring. Then the solution was poured into flat glass plate dishes. Homogenous films were obtained after drying in an air oven for 24 h at 40 °C. The thickness of the films were in the range of 20 ± 0.05 μm.

The optical studies were carried out using double beam spectrometer (Shimadzu UV probe Japan ) in the wavelength range (300-900) nm and infrared spectra were recorded using Shimadzu FTIR-8700 spectrometer in the wavelength range (400-4000) cm⁻¹ with a resolution of 4 cm⁻¹.

Results and Discussion

The Fourier Transform Infrared spectroscopy (FTIR) spectra of pure and silver nitrate doped PVA films were obtained and the results are shown in Figures 1-3. The spectra show a strong broad absorbance at 3343 cm⁻¹ for pure PVA and 3354 for 3 % and 5 % silver nitrate doped PVA. This band could be assigned to O-H stretching vibration of hydroxyl group of PVA, the band corresponding to C-H asymmetric stretching vibration occurs at 2911 cm⁻¹ and 2948 cm⁻¹ for the doped PVA. The band at 1712 cm⁻¹ corresponds to C=C stretching vibration and remains the same for 3 % dopant and shifted toward 1714 cm⁻¹ for 5 % dopant. Absorbance at 1661 cm⁻¹ corresponds to an acetyl C=O group, which could be explained on the basis of intra/inter molecular hydrogen bonding with the adjacent OH group. The sharp band 1094 cm⁻¹ corresponds to C-O stretching of acetyl groups present on the PVA backbone that remains the same for all the doped and undoped samples.

The corresponding bending, wagging of CH₂ vibrations are at 1435 and 1331 cm⁻¹ respectively Selim et al. 2005, Shin et al. 2004, Dai et al. 2002). The shift in the corresponding bands with doping
indicates that there is an interaction between PVA and silver nitrate.

Fig. 1: FTIR spectra of pure PVA thin films.

![FTIR spectra of pure PVA thin films](image)

Fig. 2: FTIR spectra of 3 % silver nitrate doped PVA thin film.

![FTIR spectra of 3% silver nitrate doped PVA thin film](image)

Fig. 3: FTIR spectra of 5 % silver nitrate doped PVA thin film.

![FTIR spectra of 5% silver nitrate doped PVA thin film](image)

The UV visible spectra of the films are presented in Fig. 4.

![Absorptance versus wavelength for pure, 3% and 5% AgNO₃ doped PVA samples](image)

Fig. 4: Absorptance versus wavelength for pure, 3% and 5% AgNO₃ doped PVA samples

No absorption in the range 350-600 nm was observed for the undoped PVA films but as the doping percentage increase, the absorbance was also increased showing a broad peak appeared at 430 nm. According to the literature, this band could be attributed to chelate formation of Ag⁺ coordinated with the hydroxyl group of PVA (Zidan 1999) or to silver particle formation (Porel et al. 2005). The absorption coefficient can be represented by the Tauc model as (Zong et al. 2006):

\[(\alpha h\nu) = B (h\nu - E_g)^{r} \] \hspace{1cm} (1)

where \(\alpha\) is the absorption coefficient, \(h\nu\) is the photon energy, \(E_g\) is the optical energy gap, \(B\) a constant known as the disorder parameter which is nearly independent of the photon energy and \(r\) is the parameter measuring type of transition.

If \(r = 2\) or \(3\) the transition is indirect allowed and forbidden, so in order to get the property of the band we need to test the above transition where could be found that \(r=3\) fitted with our results. Fig. 5 shows the absorption coefficient \((\alpha h\nu)^{1/3}\) plots of PVA and AgNO₃ doped PVA films as a function of the photon energy \((h\nu)\). The optical band gap is determined through extrapolating the linear portion to \(\alpha h\nu= 0\). As can be seen from Fig. 5, a good linear relation is fitted with equation (1) between \((2.4-1.3eV)\).

As the doped films show a red shift behavior, it can be concluded that the presence of dopant and its interaction results in the creation of new molecular dipoles, which could be results of point defects created within the band gap.
Optical Characterization of Ag Doped Poly (Vinyl Alcohol) Films

The calculated value of $\alpha$ was used to estimate the values of the extinction coefficient ($k$) using the following relation (Sharma 2006):

$$ k = \frac{\alpha \lambda}{4 \pi} \quad \ldots \ldots (2) $$

where $(\alpha)$ is the absorption coefficient and $(\lambda)$ is the incident wavelength.

Fig. 6 shows the dependence of $k$ on wavelength for all the investigated films. It can be clearly seen that the extinction coefficient increase as the doping percentage increased. The same behavior was observed with refractive index (Fig. 7), which could be determined from the following relation (Abu-Sehly and Soltan 2002):

$$ n = \left( \frac{1 + R}{1 - R} \right) \pm \left[ \left( \frac{1 + R}{1 - R} \right)^2 - (1 + k^2) \right]^{1/2} \quad \ldots \ldots (3) $$

where $R$ is the reflectance.

Wemple and Didomenico (Wemple and M. Didomenico 1971, Didomenico and Wemple 1969) used a single oscillator dispersion of the frequency dependent dielectric constant to define dispersion energy parameters $E_o$ and $E_d$. This method describes the dielectric response for transitions below the optical gap, the single oscillator model below absorption edge is defined as (Wemple and Didomenico 1971):

$$ n^2 - 1 = \frac{E_o E_d}{E_o^2 - E^2} \quad \ldots \ldots (4) $$

where $E_o$ is the single oscillator energy and $E_d$ is the dispersion energy which measures the average strength of inter band optical transition. The oscillator energy is an average of optical band gap $E_o \approx 2E_g$.

Experimental verification of eq. (4) can be obtained by plotting $(n^2-1)^{-1}$ vs. $(\nu h)^2$ as shown in Fig 8. $E_o$ and $E_d$ values were determined from the slope $(E_o E_d)^{-1}$ and intercept $(E_o/E_d)$.

The long wavelength limit of refractive index $n_\infty$ can be determined using the expression (Raj et al. 2008):

$$ n_\infty = \sqrt{\frac{1 + E_d}{E_o}} \quad \ldots \ldots (5) $$

Fig. 5: $(\alpha h\nu)^{1/3}$ versus photon energy for pure, 3% and 5% AgNO$_3$ doped PVA samples.

Fig. 6: Extinction coefficient versus wavelength for for pure, 3% and 5% AgNO$_3$ doped PVA films.

Fig. 7: Refractive index versus wavelength for pure, 3% and 5% AgNO$_3$ doped PVA samples.
The values obtained for the static dielectric constant \( \varepsilon_\infty = n^2 \) are listed in Table 1.

It can be seen that all parameters affected by doping and that the value of the optical gap which determined by this model were in good agreement with the values obtained by the Tauc model.

![Graph](image)

Table 1: The optical parameters of AgNO\(_3\) doped PVA.

<table>
<thead>
<tr>
<th>Sample</th>
<th>( E_d ) (eV)</th>
<th>( E_o ) (meV)</th>
<th>( E_g ) (eV)</th>
<th>( n_\infty )</th>
<th>( \varepsilon_\infty )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pure PVA</td>
<td>8.700</td>
<td>5.84</td>
<td>2.92</td>
<td>1.58</td>
<td>2.50</td>
</tr>
<tr>
<td>3% AgNO(_3) doped PVA</td>
<td>8.162</td>
<td>3.55</td>
<td>1.78</td>
<td>1.80</td>
<td>3.24</td>
</tr>
<tr>
<td>5% AgNO(_3) doped PVA</td>
<td>8.400</td>
<td>2.99</td>
<td>1.5</td>
<td>1.95</td>
<td>3.80</td>
</tr>
</tbody>
</table>

Conclusions

1- FTIR measurements reveal that AgNO\(_3\) interacts with the PVA polymer, as can be seen from the shift of corresponding bands.

2- The AgNO\(_3\) dopant affects the optical energy gap by reducing its value to 1.3 eV for the 5% doping.

3- A single oscillator model indicates that the static refractive index increased as the dopant percentage increase and the values of \( E_d \) and \( E_o \) were determined.

Literature Cited


https://scholarworks.uark.edu/jaas/vol64/iss1/1
Optical Characterization of Ag Doped Poly (Vinyl Alcohol) Films


Population Status of the Southern Cavefish, *Typhlichthys subterraneus* in Arkansas

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Abstract

We summarize the results of our study on the status of the southern cavefish (*Typhlichthys subterraneus*) in Arkansas. Its presence in the state represents the western-southern limits of its distribution. Four localities have been confirmed that contain individuals of this species: Richardson Cave (Fulton County), Alexander Cave/Clark Spring (Stone County), Ennis Cave (Stone County), and Lake Norfork (Baxter County). A fifth locality has been cited as a well in Randolph County, but because the exact location is unknown, its presence has not been confirmed. A number of unconfirmed localities for “cavefishes” in the region has not been included in this report. Populations of this species in Arkansas seem to be small (less than 100 individuals) which is common among populations of hypogean amblonyopsids elsewhere. All the confirmed localities are in areas either under controlled access by the private owners or by the federal government. No immediate threat to these populations was found by either overcollecting or other anthropogenic causes. Yet long-term monitoring of the recharge zones is recommended.

Introduction

Because of both small population sizes and restriction to one or very few localities hypogean (cave, phreatic) species of fishes are usually considered threatened, if not endangered, taxa worldwide (Romero and Paulson 2001, Romero et al. 2009). In order to understand the conservation status of one of the species of hypogean fishes of Arkansas, we conducted both field and archival research about *Typhlichthys subterraneus* in the state.

Materials and methods

We tried to obtain information on every single record for *T. subterraneus* in the state of Arkansas. Data were compiled from both scientific and nontechnical literature, from collections of museums and similar institutions, and from unpublished sightings by reliable observers, including those using photographs or videotape recordings. We included in this compilation only those reports from scientific publications and popular accounts that provide sufficient information, such as clear descriptions, videorecordings or photographs, to permit unambiguous species identification. Original sources were used wherever possible. All unpublished material has been deposited in the libraries of one of us (Romero). We also tried to verify independently the identification of every specimen in museum collections. We also visited every single locality for which there had been a record of the southern cavefish at least once and interviewed all people who claim to have first hand knowledge of this fish for that locality. Visits to the caves took place during 2006 and 2007 (see Table 1). Every single body of water that might support individuals of the southern cavefish was also visited. Each one of those pools and/or streams was observed by two or more observers for at least 30 min. During that time we used flashlights, infrared goggles (Bushnell) and a digital video camera recorder with infrared capabilities (SONY Wide LCD, 3.0 mega pixels) because responses to light have been reported for this species (Green and Romero 1997). We also looked for any signs of human disturbance that may affect the quality of the underground water in the areas adjacent to the caves visited.

Results

**Fulton County: Richardson Cave**

This cave also known as Martin Cave has been visited four times in search for *T. subterraneus*. On 3 February 1979 a team from Arkansas State University (ASU) visited and collected one specimen and saw 20 more. The specimen collected is at the fish collection of ASU under the catalog number ASUMZ 9064. The same team visited this cave a week later and could not see a single individual (Paige et al. 1981). Dunivan et al. (1982) reported one individual. We visited this cave twice, on 22 and 23 of June 2007. The second of
these visits consisted in a reconnaissance of the entire cave including all of its bodies of water. No fish were seen.

**Randolph County:**
This is the most mysterious record for *Typhlichthys subterraneus* in Arkansas. This is based on at least one specimen at the Museum of Zoology of the University of Michigan (UMMZ 133844). According to the letter accompanying the two specimens originally sent these specimens were collected “from a well, Randolph County, collected in the spring of 1940.” Since the letter requested that one of the specimens be returned to the sender, that might explain why despite the fact that two were sent to the museum, only one is in its collection. The letter was signed by Byron C. Marshall, the proprietor of a company called Ozark Biological Laboratories. Their standard length were 53 and 58 mm respectively. The smallest one was returned to Marshall who did not want to divulge the locality of the well where these specimens were collected.

D.W. Nelson (*pers. comm.*) reported to us that “Interestingly, Marshall had previously sent to Hubbs two specimens (of 4 total) of *Amblyopsis rosae* from a collection that he had made in Downer’s Cave, Sarcoxie, Missouri.” We may never learn what is the exact location for this (these) specimen(s). We visited Pocahontas on 18 June 2007 and interviewed several local officials and archivists. Nobody has heard of any well from which blind/depigmented fish have been pumped out.

**Stone County: Alexander Cave**
Also known as Castle Cave, this is the location in which *Typhlichthys subterraneus* has been seen more frequently and in larger numbers for the state of Arkansas. This cave is connected with a water resurgence known as Clark Spring that has been explored in several occasions using SCUBA equipment and that has resulted in several sightings including some recorded on video tape. The first recorded sighting is from 1975 by Mr. Tim Ernst (Harvey 1975 cited in Robison and Buchanan 1988). The largest numbers of individuals were seen when scuba diving through Clark Spring and the sightings at the pool location in the cave produces numbers between two and five.

**Stone County: Ennis Cave**
This is the most recent locality record for *Typhlichthys* in Arkansas. This cave is owned by the Rose Family and the steward is Mr. Tim McClain. This is a gated cave with a perennial stream where the fish can be seen. Ennis Cave was visited by G.O. Graening, D. Fenolio and E. Corfey on 7 May 2004 and one individual collected (Graening et al. 2005). We visited it on 26 May 2007 and observed one fish which quickly disappeared through a crevice.

**Baxter County: Lake Norfork**
On 20 February 2009 an individual of *Typhlichthys subterraneus* was collected at Lake Norfork (15S 560987.4mE 4030555.0mW) by Steve Teems and deposited at the ASU museum collection under number 13067. This is an unusual finding since obligatory cave fish species are rarely collected outside the hypogean environment.

**Conservation status**
*Typhlichthys subterraneus* is classified as Vulnerable (VU D2) by the World Conservation Monitoring Centre (WCMC) (Romero 1998). Global Rank: G4 apparently secure. The global rank of G4 is usually assigned to species that have been recorded from more than 100 localities. Although this species is known from sufficient localities to merit the rank of G4, its position in cave ecosystems as a predator suggests a lower (G3) rank.

Its protection status in the United States is as follows: Alabama: Threatened, Protected; Arkansas: Inventory Element; Georgia: Rare; Indiana: Endangered; Kentucky: Special concern; Missouri: Watch List; Oklahoma: record extirpated because of misidentification; Tennessee: Deemed in need of management (Noltie and Wicks 2001). Harvey (1975) considered in 1975 that *Typhlichthys subterraneus* in Arkansas was not really endangered because the only locality known there besides the unnamed well was Alexander Cave that was well protected.

**Potential threats**
Potential threats to aquatic hypogean fauna in general and cave fishes in particular have been listed by Keith (1988). Below we present a modified version of that list:

1. Water quantity: changes in the hydrological regime due to impoundments, quarrying, welling and/or water extraction.
2. Water quality:
   a.) Groundwater pollution by agrochemicals, sewage, accidental spills of hazardous materials, oil and/or gas exploration/exploitation, and intentional dumping of hazardous waste into sinkholes and sinking streams.
b.) Sedimentation and runoff as a consequence of farming activities, logging and/or deforestation, road and building construction (urbanization) as well as runoff and erosion from rainfall.
3. Overcollecting
4. Cave habitat alteration to either facilitate recreational activities and/or gating that may prevent bats and other fauna to come into the cave and carry with them potential nutrients.

During our visits to the three known localities for Typhlichthys in Arkansas, we did not observe any of the above-ground anthropogenic activities listed above. That does not mean that there is no potential for environmental impacts in the future due to water pollution in the recharge zones of surrounding areas (Aley and Aley 1997). Such an occurrence can cause a large mortality event such as the one that took place in November of 1981 when about 1,000 southern cavefish individuals and ca. 10,000 Salem cave crayfish (Cambarus hubrichti) were killed in Meramec Spring, Missouri, because of a fertilizer pipeline failure that released 80,000 L of liquid ammonium nitrate (Crunkilton 1982, 1985, Weaver 1992).

Access to all three caves (Alexander, Richardson, and Ennis) is controlled in varying degrees by the cave owners by gating (Alexander), constant human presence (Ennis) or special permit (Richardson). The Clark Spring entrance to Alexander Cave can only be utilized under special permit by the U.S. Forest Service since that entrance is on land under the management of that federal agency. That spring can only be penetrated using SCUBA equipment and because of its characteristics only experienced scuba divers can explore it. Therefore overcollecting does not seem to be a concern. Only Alexander and Ennis caves had been slightly altered by the owners to facilitate exploration and only at certain points. None of those alterations seem to have impacted the bodies of water where the fish could be found.

**Conclusions and recommendations**

We found no indication that the populations of Typhlichthys in Arkansas are in need of urgent actions by either federal or state agencies and/or private individuals. However, because of the potential impact that some activities may have in the future, we recommend periodic monitoring of the anthropogenic activities listed above that may impact the conservation status of those populations.

**Acknowledgments**

G.O. Graening, The Nature Conservancy Arkansas Field Office, provided very valuable first hand information collected by him from his field work in Arkansas. David Kampwerth from the U.S. Fish and Wildlife Service provided useful information and encouragement. Bob Koch of the Ozark Cave Diving Alliance provided us with valuable unpublished information and an underwater video of Typhlichthys in Clark Spring. Ron Lather took us to the pool at Ennis Cave where fish have been reported. Douglas W. Nelson, Collections Manager, Fish Division, Museum of Zoology, provided information about the specimen of *T. subterraneus* from a well in Randolph County deposited at the University of Michigan. Randy Rose, owner of Ennis Cave, provided us with access to Ennis Cave. R.C. Schroeder, Association of Arkansas Cave Studies, served as a guide during our visit to Alexander Cave. James Whalen, United States Department of Agriculture Forest Service, provided us with the permit to even observe the fish and visit Alexander Cave via Clark Spring. Darrel Williams, owner of Richardson Cave, allowed us to visit that cave. Brian Wagner provided us with the specimen of *T. subterraneus* from Lake Norfork. This research was funded by a contract between the Arkansas Game and Fish Commission and Arkansas State University.

**Literature cited**


Graening GO, ME Slay and AV Brown. (Department of Biological Sciences, University of Arkansas at Fayetteville). 2001. Subterranean biodiversity in the Ozark Plateaus of Arkansas. Arkansas Game and Fish Commission and Arkansas Department of Natural Heritage. 52p.
Table 1. Confirmed localities of *T. subterraneus* in Arkansas.

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<thead>
<tr>
<th>County</th>
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<td>21</td>
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<td>1940</td>
<td>2</td>
<td>Woods and Inger 1975</td>
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Characterization of Secondary Organic Aerosol (SOA) formed by the Reaction of β-caryophyllene, Soot and Ozone: Climate Impact

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Abstract

Diesel soot (black carbon, BC) is an important light absorbing aerosol component in atmosphere that can cause tropospheric heating. Laboratory studies have found it to be unreactive to ozone at ambient temperature. The low uptake coefficient i.e., $γ_{300 \text{ K}} = 2 \times 10^{-7}$, of the soot-O$_3$ reaction indicates a low probability of irreversible O$_3$ loss from gas phase to surface-adsorbed product (Particle phase). This shows clearly that at low temperature soot is not reactive with atmospheric oxidants. In contrast, sesquiterpenes (SQT) such as β-caryophyllene (C$_{15}$H$_{24}$), which are produced primarily by plants, are extremely reactive with ozone. For example, the residence time of β-caryophyllene in the atmosphere is only 2 min in the presence of 60 ppb ozone. Thus, ozonolysis reaction of β-caryophyllene is expected to be a significant source of biogenic secondary organic aerosols. These oxidized products may condense onto soot particles, and a question arises as to how they will partition between the soot surface, vapor phase, and aqueous aerosol phases. Liquid chromatography- mass spectrometry (LC/MS), Fourier transform infrared (FTIR) and UV-Vis spectroscopies are being used to study the β-caryophyllene-dark ozonolysis reaction at low ozone levels (40-60 ppb). Products identified include low molecular weight highly volatile and water soluble products such as formaldehyde, acetaldehyde, acetone, and acetic acid. Also identified are high molecular weight components (~350 Dalton) with lower water solubility and vapor pressures. The SOA coatings of these SQTs on soot are being evaluated to determine their hygroscopicity. As these compounds absorb in the IR and UV-Vis they can add to radiative forcing by submicron aerosols and need to be better understood for climate modeling.

Introduction

Sesquiterpenes (SQT, C$_{15}$H$_{24}$) are one of the important sources of non-methane hydrocarbons in the atmosphere that are produced primarily by plants, mainly conifers and have been found to be precursors of secondary organic aerosols (SOA) (Baltensperger et al. 2005). SQT have very low vapor pressures and SOA are formed when these biogenic precursor species react with atmospheric oxidants at ambient temperature (298-300K). These biogenic hydrocarbons (SQT) have a very short lifetime and they are so reactive with atmospheric oxidants (e.g. O$_3$, OH, NO$_3$) that it is very difficult to measure them directly in the atmosphere. However, their oxidized products are highly volatile and they can influence radiative balance directly by absorbing and scattering radiation as coatings on carbonaceous aerosols. Primary carbonaceous aerosol, such as soot, has been found to be reactive towards ozone (O$_3$) at higher temperature in the range of 473-573K (Smith DM et al.1996). These “black carbon species” are important light absorbing aerosols and their surface oxidations at room temperature with ozone are thought to be very slow. This paper provides a summary of an examination of ozone reaction with soot and an upper limit for uptake on the surface of a standard diesel soot (NIST 2975), as well as preliminary chemical characterization of SOA particles generated from the biogenic precursor β-caryophyllene and the ubiquitous atmospheric oxidant O$_3$. A specific focus in our analysis has been on the evaluation of water soluble species from the ozone reaction with this model sesquiterpene.

Materials and Methods

Soot-O$_3$ reaction was carried out in a simplified reaction chamber (Fig. 1). NIST standard diesel soot 2975 (0.05-0.08 mg) was placed inside the reaction chamber. N$_2$ gas flowed continuously through the chamber at a rate of 275 cm$^3$ min$^{-1}$ at 298-300 K and atmospheric pressure. O$_3$ gas was generated by passing atmospheric air through an O$_3$ generator (Dasibi model 1009 CP) and the air flow was kept constant at 1.21 L min$^{-1}$. This instrument also monitors the ozone concentration continuously using long-path UV
absorption to assure a specific ozone concentration is maintained during the soot exposure. At the end of every reaction FTIR spectra of ozonated soot were obtained on Nicolet 6700 Fourier transform infrared spectroscopy (FTIR)-diffuse reflectance infrared Fourier transform (DRIFTS) technique. All the individual parts of reaction setup were connected by using 1/8 inch Teflon® tubing connected with Teflon® Swagelok® fittings to assure a gas-tight system. The experimental setup was slightly modified for the β-caryophyllene-dark ozonolysis reaction. The same ozone generator was used and two impinger tubes of volume of 30 ml were fitted in parallel to allow the carrier gas to equilibrate with the organic vapor pressure and then allow ozone to react with the vapor. The ozone concentration for this reaction was maintained at 60 ppb ozone and the oxidized products, gases and aerosols were bubbled through 10 ml water in another impinger tube that allowed for water soluble products to be collected for analysis.

FTIR spectra of ozonated soot showed no indication of any oxidized products even after long time O₃ exposures (60 ppbv) on diesel soot at 300K, i.e. no measureable product formation was observed (spectra not shown). The experimental observation was used to calculate an upper level limit on the uptake coefficient (γ) for this soot-O₃ reaction. The experimentally obtained low γ value i.e., $\gamma_{300K}=2\times10^{-7}$ of soot-O₃ reaction indicated a low probability of irreversible O₃ loss from gas phase to surface adsorbed products (particle phase). By analyzing uptake-coefficient value, it can be concluded that at ambient temperature soot is unreactive to atmospheric oxidant.

All the parts of this reaction setup were connected by using 1/8 inch Teflon® tubing connected with Teflon® Swagelok® fittings. Spectra of these oxidized products were obtained from FTIR-spectroscopy using attenuated total reflectance (ATR) technique using a Zn-Se crystal in spectral region of 650-4000 cm⁻¹ at resolution 4 cm⁻¹. Spectra were averaged using 64 scans. UV-Vis absorption spectra of these oxidized products were obtained from 280-800 nm by using UV-Vis Beckman DU 600 instrument. LC-MS spectra were obtained by using an Agilent 1100 series LC/MSD Ion trap spectrometer. A total of 10μL solution was introduced into a Liquid chromatography (LC) column for chromatographic separation prior to MS analysis. Column flow was adjusted to 0.400 mL min⁻¹ and a 60% water/40% methanol mixture was used as the carrier solvent. The LC/MS ion source was operated in the Electrospray Ionization (ESI) mode to obtain mass spectra.

Results and Discussion

FTIR spectra of ozonated soot showed no indication of any oxidized products even after long time O₃ exposures (60 ppbv) on diesel soot at 300K, i.e. no measureable product formation was observed (spectra not shown). The experimental observation was used to calculate an upper level limit on the uptake coefficient (γ) for this soot-O₃ reaction. The experimentally obtained low γ value i.e., $\gamma_{300K}=2\times10^{-7}$ of soot-O₃ reaction indicated a low probability of irreversible O₃ loss from gas phase to surface adsorbed products (particle phase). By analyzing uptake-coefficient value, it can be concluded that at ambient temperature soot is unreactive to atmospheric oxidant. An upper-estimate of the O₃ uptake coefficient, γ value was calculated from eq.1;

$$\gamma = 4KV/\omega S$$

Where K = rate constant of O₃ loss, $7.2\times10^4$ min⁻¹ ppm⁻¹ at 300K (experimentally obtained); V = volume of reaction zone, $1.437\times10^{-6}$m³; $\omega$ = average molecular speed or root mean square (r.m.s.) velocity, 23690 m min⁻¹; S = specific surface area of soot; 80-87 m² gm⁻¹.

IR stretching bands at 1730 and 2850 cm⁻¹ in Fig. 3 indicated the presence of carbonyl group (aldehyde or ketone) (Marley et al 1993) and some alkane compounds in the water soluble oxidized product respectively which was produced during ozonolysis reaction of Beta-caryophyllene. The band at 1640 cm⁻¹.
Secondary Organic Aerosol (SOA) formed by the Reaction of β-caryophyllene Coated Soot and Ozone: Climate Impact

is basically a peak from liquid water adsorption (Marley et al. 1994). UV-Vis spectra in Fig. 4 supported this fact by indicating a shift of absorbance maxima to longer wavelength; from 250 to 300 nm. This bathochromic shift may occur due to the presence of some conjugated species in this oxidized sample.

LC-MS, FTIR and UV-Vis spectroscopies were used to identify the products including low molecular weight highly volatile and water soluble products such as formaldehyde, acetaldehyde, acetic acid and acetone. Component of low molecular weight like formaldehyde was reported in a recent paper (Winterhalter et al. 2009).

Further work is underway to examine the effects of acid catalyzed carbonaceous seed particles which may increase the formation of SOA and to determine the gas/particle partitioning coefficient of β-caryophyllene-ozonolysis reaction products in presence of soot surface or carbonaceous aerosol and to establish the organic reaction mechanisms (e.g. aldol condensation reaction, etc.) to determine the possible pathways for oligomer formation.

Acknowledgments

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Literature Cited


Status and Distribution of the Gapped Ringed Crayfish, *Orconectes neglectus chaenodactylus*, in Arkansas

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Abstract

*Orconectes neglectus chaenodactylus*, the gapped ringed crayfish, is an uncommon and poorly-known, stream-dwelling crayfish that is endemic to the central White River basin of Arkansas and Missouri. This study surveyed a semi-random selection of stream sites in the Arkansas portion of this range in order to characterize the crayfish communities and evaluate the status of *O. n. chaenodactylus* in Arkansas. Collections of a total of 1,107 individual crayfish specimens were made at 45 sites, including 497 *O. n. chaenodactylus* from 21 sites. *Orconectes punctimanus* was the crayfish species most commonly associated with *O. n. chaenodactylus*, occurring at 71% of sites occupied by *O. n. chaenodactylus*. *Orconectes n. chaenodactylus* was found in streams not significantly different from the median characteristics of streams sampled in the study. It is our opinion that *O. n. chaenodactylus* is uncommon in Arkansas, and of only moderate concern due to its limited distribution in the state.

Introduction

The ringed crayfish, *Orconectes neglectus*, was originally described from Mill Creek in Wabaunsee County, Kansas (Faxon 1885). It is a medium-sized, stream-dwelling crayfish, typically growing to a total size of 30.5 – 96.5 mm (Pflieger 1996). It has broad, heavy chelae, a rostrum with a trough-like central depression, and male gonopods with two elongate, slightly curved processes (Pflieger 1996).

The gapped ringed crayfish, *Orconectes neglectus chaenodactylus*, was recognized as a distinct subspecies based on specimens from White Creek in Douglas County, Missouri (Williams 1952). It differs from the nominate subspecies in having chelae with more slender fingers with a broad gap between the fingers and a smaller, shorter rostrum (Williams 1952). In addition to its long-standing recognition based on morphological characteristics, more recent genetic studies suggest the possibility that it is a distinct species (Crandall and Fitzpatrick 1996, Crandall 1998, Dillman et al. 2007).

This crayfish is a tertiary burrower occupying cavities excavated under rocks seated in gravel and coming out at night to forage (Pflieger 1996). Price and Payne (1979) found females with eggs from mid-April to mid-June in North Sylamore Creek, Stone County, Arkansas. They found the mean size at maturity to be 13.5 mm CL, based on the minimum size at which they observed a 50% probability of males being form-I, and observed that 50% reach this size during their first summer. Further, they noted adults molting 4 times in a year, in contrast to the standard expectation of 2 molts per year. Most adults live 2 to 3 years, with older individuals being rare. Price and Payne (1984a,b) observed young-of-the-year to appear in May in North Sylamore Creek and noted no gender differences in growth.

*O. n. chaenodactylus* has a limited and poorly understood distribution. Original work suggested its endemism to the North Fork White River basin in Missouri (Williams 1954). It was first collected by 1967 in Arkansas (Robison 2002, Smithsonian lot USNM131642). Populations were originally thought to be restricted to the North Fork White River, and intergrades were hypothesized between it and *O. n. neglectus* throughout the remainder of the White River basin (Hobbs 1989, Pflieger 1996, Williams 1952). It has subsequently been reported from a few divergent locations in Arkansas, primarily in the North Fork White River and Sylamore Creek basins. It has recently been discovered, due to a suspected introduction, in the Spring River basin (Rabalais and Magoullick 2006). Taylor et al. (2007) considered it to be "vulnerable" and The Nature Conservancy ranks it as G5T3S2, meaning it is globally secure as a species, found locally in a restricted range as a subspecies, and very rare within the state.

The objective of this study was to document the
diversity and distribution of the crayfish fauna of the North Fork White and Middle White river basins in Arkansas and establish baseline distribution and status of *O. n. chaenodactylus*.

**Methods**

**Study Area and Site Selection**

This study focused on the portions of the North Fork White and Middle White river basins in northern Arkansas. Based on the National Hydrology Dataset (NHD), these hydrologic units comprise 5,045 identified stream segments totaling 97,872 km. The Arkansas portion of these units includes parts of Baxter, Cleburne, Fulton, Independence, Izard, Searcy, Sharp, and Stone counties. Since these areas are largely in private ownership, road access to sampling sites was particularly important. U. S. Census Bureau data on roads in these counties was combined with the NHD data using ArcMap™ GIS software to identify stream segments intersected by roads. A random subset of these segments was selected for sampling by generating a random number between 0 and 19 as a start point, and then every 20th segment listed in the pooled list of accessible stream segments was chosen. Since the NHD segments were generally listed clustered by proximity to one another, this reduced the selection of clustered sampling sites and provided a fairly uniform distribution of sites. This process was repeated for each basin and resulted in selection of 72 stream segments as potential sample sites. The selection is considered to be semi-random because of its dependence on road crossings.

Because headwater streams are more numerous and more easily bridged than larger streams, it was acknowledged that site selection was biased toward headwater streams. Some of these headwater streams were intermittent and did not hold water or crayfish when visited for sampling, or were inaccessible due to fencing, posting, and/or lack of landowner permission. When this was the case, the site was omitted or replaced with a nearby site on a larger stream that was not randomly selected for sampling. Some selected segments turned out to be erroneously assigned to the study basins, and were treated in the same manner.

**Sampling Methods**

The majority of collections were made between September and November 2006. Comparable data for one collection in October 2005 was also included. All available habitats at selected sites were sampled using primarily dip nets or 1-m minnow seines when stream size or flow made dip nets ineffective. This was supplemented by approximately 30 person-minutes of visual search and hand capture of crayfish by overturning larger rocks at sites where such rocks were present and water clarity allowed observation of crayfish presence when such rocks were lifted. At larger river sites, hand capture was completed using snorkeling. As tertiary burrowing crayfish rarely burrow, excavation of burrows was not necessary.

At each sample site, latitude and longitude coordinates in decimal degrees (North American Datum 1927) were recorded for the sample location.

Crayfish were sorted by perceived species, gender determined, and measured to the nearest mm carapace length (CL). A series of voucher specimens including males and females of each species was also taken. All voucher specimens were preserved in 70% ethanol, identification to species verified by the second author, and deposited in the collection of the Illinois Natural History Survey or the AGFC Nongame Aquatics Program reference collection.

**Results**

Seventy two steam segments were targeted for sampling within the North Fork White River (31 sites) and Middle White River basins (41 sites). Due to lack of water or access, several sites were deleted or relocated, resulting in samples actually being conducted at 45 sites (North Fork White 22 sites, Middle White River - 23 sites). Sites sampled are mapped for each subspecies of *O. neglectus* collected in Figure 1. Crayfish species and numbers collected by site are noted in Table 1.

Nine crayfish species (and 2 subspecies), comprising a total of 1,107 specimens, were collected in this study. The most abundant taxon was *O. neglectus chaenodactylus*, followed by the other species encountered (summarized in Table 2). There were also 14 *O. neglectus* from one site that have not been assigned to subspecies and 4 female *Orconectes* from 2 sites that could not be identified to species. The most commonly encountered taxon in the study was *O. punctimanus*, found at 34 sites, followed by *O. n. chaenodactylus*, *O. ozarkae*, and other species each found at fewer than 10 sites (Table 2). Mean lengths and gender frequencies by species are displayed in Table 3. Length frequencies of *O. neglectus* collected (carapace length in mm) are provided by subspecies in Figure 2.
### Status and Distribution of the Gapped Ringed Crayfish, *Orconectes neglectus chaenodactylus*, in Arkansas

Table 1: Site locations and crayfish species and numbers collected by site. Collections are grouped by basin. Latitude and longitude coordinates are in decimal degrees, North American Datum 1927.

#### Middle White Basin

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Status and Distribution of the Gapped Ringed Crayfish, *Orconectes neglectus chaenodactylus*, in Arkansas

Figure 1: Map of north-central Arkansas depicting watershed areas included in this study. Black triangles indicate sites where *Orconectes neglectus chaenodactylus* was encountered. Small circles indicate sites where *O. n. chaenodactylus* was not encountered. Larger rings indicate sites where *O. n. neglectus* was encountered.

Table 2: Numbers of crayfish collected in study by species, % of total, number of sites occupied, and % of sites occupied.

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</tbody>
</table>

Species associations and dominance are reported in Table 4. *O. n. chaenodactylus*, a Species of Greatest Conservation Need (Anderson 2006), co-occurred repeatedly with three species, *O. punctimanus* (71%), *O. ozarkae* (24%), and *O. n. neglectus* (14%). It also co-occurred at a single site with *C. hubbsi* and *O. longidigitus*. Species associations with *O. n. chaenodactylus* were also examined using the metrics of dominance, constancy, and fidelity (Table 4), as described by Pfieger (1978). *O. n. chaenodactylus* was the dominant species where found, comprising an average of 65% of the crayfish collected at those sites. Constancy results indicated that *O. punctimanus* was the associated species found most often at sites having *O. n. chaenodactylus* (75%). Since *O. punctimanus*
was found at 76% of all sites, almost identical to its frequency of occurrence with *O. n. chaenodactylus*, this does not imply any selection by these species for similar site characteristics. Fidelity estimates, incorporating all sampled sites regardless of *O. n. chaenodactylus*’ presence, were greatest for *O. n. neglectus* (50%), an artifact of the underrepresentation of the true range of *O. n. neglectus* among the sites included in analysis.

Table 4: *Orconectes neglectus chaenodactylus* (*O.n.c.*) species associations, including dominance, constancy, and fidelity, after Pfieger (1978). Dominance = the percentage of all crayfish collected at sites with *O. n. chaenodactylus* that are the given species. Constancy = the percentage of *O. n. chaenodactylus* sites also having the given species. Fidelity = the percentage of sites having the given species that also have *O. n. chaenodactylus*.

<table>
<thead>
<tr>
<th>Species Association</th>
<th>Dominance (%) at <em>O.n.c.</em> sites</th>
<th>Constancy (%) at <em>O.n.c.</em> sites</th>
<th>Fidelity (%) at <em>O.n.c.</em> sites</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>O. n. chaenodactylus</em></td>
<td>65</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td><em>O. n. neglectus</em></td>
<td>19</td>
<td>-</td>
<td>20</td>
</tr>
<tr>
<td><em>O. ozarkae</em></td>
<td>75</td>
<td>-</td>
<td>5</td>
</tr>
<tr>
<td><em>O. punctimanus</em></td>
<td>50</td>
<td>5</td>
<td>33</td>
</tr>
</tbody>
</table>

**Discussion**

**Distribution**

*O. neglectus* was described by Faxon (1885) from what turns out to be a small, disjunct population in Mill Creek, Wabaunsee County, Kansas. Williams (1952) recognized *O. n. chaenodactylus* as a distinct subspecies in the North Fork White River basin in Missouri. The subspecies was later recognized from the Arkansas portion of this basin and nearby basins in the Middle White River area. Collections held at the Smithsonian include four lots from Arkansas identified as *O. n. chaenodactylus*. Three of these lots fall within the Sylamore Creek area (USNM131644, USNM131642, and USNM220143). The fourth lot (USNM177056) is from War Eagle Creek in Madison County, far outside the suspected range of *O. n. chaenodactylus*. This record is considered suspect and should be reexamined, as in extensive sampling in that area by Wagner et al. (2010) collected *O. n. neglectus*. 

Table 3: Crayfish mean carapace length (CL) in mm, standard deviation (sd), and gender breakdown by species.

<table>
<thead>
<tr>
<th>Species (N)</th>
<th>Mean CL</th>
<th>s.d CL</th>
<th>Males</th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>C. hubbsi</em> (7)</td>
<td>-</td>
<td>-</td>
<td>1 (14%)</td>
<td>6 (86%)</td>
</tr>
<tr>
<td><em>F. fodiens</em> (5)</td>
<td>20.6</td>
<td>1.8</td>
<td>2 (40%)</td>
<td>3 (60%)</td>
</tr>
<tr>
<td><em>O. longidigitus</em> (3)</td>
<td>-</td>
<td>-</td>
<td>2 (52%)</td>
<td>1 (48%)</td>
</tr>
<tr>
<td><em>O. meeki meeki</em> (20)</td>
<td>19.8</td>
<td>5.6</td>
<td>9 (45%)</td>
<td>11 (55%)</td>
</tr>
<tr>
<td><em>O. n. chaenodactylus</em> (497)</td>
<td>19.0</td>
<td>6.3</td>
<td>231 (46%)</td>
<td>266 (54%)</td>
</tr>
<tr>
<td><em>O. n. neglectus</em> (137)</td>
<td>23.4</td>
<td>9.2</td>
<td>75 (55%)</td>
<td>62 (45%)</td>
</tr>
<tr>
<td><em>O. neglectus</em> not assigned to ssp (14)</td>
<td>20.5</td>
<td>2.8</td>
<td>8 (57%)</td>
<td>6 (43%)</td>
</tr>
<tr>
<td><em>O. ozarkae</em> (147)</td>
<td>23.8</td>
<td>6.0</td>
<td>82 (56%)</td>
<td>65 (44%)</td>
</tr>
<tr>
<td><em>O. punctimanus</em> (254)</td>
<td>20.7</td>
<td>5.1</td>
<td>123 (48%)</td>
<td>131 (52%)</td>
</tr>
<tr>
<td><em>O. virilis</em> (47)</td>
<td>50.0</td>
<td>4.2</td>
<td>1 (50%)</td>
<td>1 (50%)</td>
</tr>
<tr>
<td><em>P. acutus</em> (19)</td>
<td>15.6</td>
<td>5.4</td>
<td>4 (21%)</td>
<td>15 (79%)</td>
</tr>
</tbody>
</table>
Status and Distribution of the Gapped Ringed Crayfish, *Orconectes neglectus chaenodactylus*, in Arkansas

as the most common species but no *O. n. chaenodactylus* specimens were encountered.

This study greatly expanded the documented distribution of this crayfish by documenting its presence at several sites within its suspected range. It appears to be a common crayfish in tributaries of Lake Norfork, throughout the Sylamore Creek sub-basin, in the White River downstream to Batesville, and in a few other tributaries in the Middle White River basin. It was previously reported that the 2 subspecies of *O. neglectus* intergraded over a wide area, so it surprised us to observe clearly recognizable populations of both subspecies co-occurring at a few sites. These situations are currently being examined in more detail using genetic analyses.

Genetic data implies that *O. n. chaenodactylus* is a distinct species (Crandall and Fitzpatrick 1996, Crandall 1998, Dillman et al. 2007). Recent studies show that the situation is much more complex, with *O. neglectus* possibly containing several cryptic species (Dillman et al. 2007). This shines some doubt on the true distribution of all lineages within *O. neglectus*, but we are reasonably confident that *O. n. chaenodactylus* will be found to be a valid taxon at some level and that its range includes the North Fork White River basin and portions of the Middle White River basin. It is interesting to observe that some sites in this area are occupied by 2 or more likely taxa of *O. neglectus*. The distribution and population levels of *O. n. chaenodactylus* in Missouri are understood primarily by Pflieger's (1996) work, with limited work since (R. J. DiStefano, Missouri Department of Conservation, pers. comm.).

Length Frequency

Visual inspection of the length frequency graph for *O. n. neglectus* seems to indicate 2 or possibly 3 age classes, whereas there are less well-defined classes for *O. n. chaenodactylus* (Figure 2). However, the variability in individual growth rates results in overlapping age classes that are not readily evident in these graphs. This could be confounded by the fact that the length measurements are taken over a 3-month time period and combined among several sites which may have different growth rates. Price and Payne (1984a) sampled North Sylamore Creek on a monthly basis and their length frequency analysis suggested 5 overlapping, normally-distributed age classes. Their oldest age class had an upper CL of 35.4 mm, whereas our largest *O. n. chaenodactylus* had a CL of 43 mm. They found only males over 31 mm, while we found only males over 39 mm. On closer inspection, we would note that our largest specimens came from collections from the White River, suggesting that growth rates in this large river habitat could be significantly greater than those in smaller streams, such as North Sylamore Creek. As the White River sites sampled were within the reservoir release created trout-waters and North Sylamore Creek is a spring-fed stream, we do not think that the difference in growth rates can be explained by a major difference in water temperature.

Recommendations

*O. n. chaenodactylus* appears to have a localized distribution in northcentral Arkansas (and into Missouri), but it is abundant at sites where it does occur. It has been introduced into the South Fork Spring River, where it is proving to be invasive and displacing other species. While the subspecies’ limited range causes it to be of some conservation concern, its abundance where found reduces its priority for conservation efforts.

Acknowledgments

Field assistance was provided by K. Irwin, M. Oliver, and S. Todd of the Arkansas Game and Fish Commission. C. Dillman of Saint Louis University assisted with some species identifications.

Literature Cited


Assessing the Vertical Accuracy of Arkansas Five-Meter Digital Elevation Model for Different Physiographic Regions

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Abstract

Digital Elevation Models (DEMs) represent the elevation of the earth’s surface. Scientists and decision makers have used DEMs to address questions relating to the earth’s landscape. This study assessed the vertical accuracy of Arkansas 5-meter raster DEM dataset produced in 2006 photogrammetrically, for three physiographic regions that represented a variation of elevations. The vertical accuracy of the DEM datasets was assessed by comparing their elevations to elevations collected using a surveying carrier phase Global Position System (GPS). To make comparisons between physiographic regions, paired t-tests using absolute elevation value difference and elevation difference along with the Absolute Mean Range Value (AMRV) was also computed. The results of the study revealed that 5-meter DEM is statistically different from the true elevation for the state with a mean absolute difference elevation error of 2.90 meters. The mean absolute elevation error for the Boston Mountains, the Ouachita Mountains, and the Mississippi Alluvial Plain physiographic regions are 4.98, 2.81, and 1.06 meters, respectively. The absolute mean range value (AMRV) revealed that in the Mississippi Alluvial Plain, the DEM might be problematic, since there is more error fluctuation (AMRV = 12.421\%) across a smaller distribution of true elevation values compared to 1.283\% for the Boston Mountains and 1.271\% for the Ouachita Mountains physiographic regions.

Introduction

With the increased demand for the earth’s limited resources, reliable assessments of landscapes are needed for natural resource conservation and for the understanding of human impacts on natural resources (Smith and Atkinson 2001). In the past, Geographic Information Systems (GISs) were used primarily as a descriptive tool, but now, they are also used as a tool for decision-making (Weih and Smith 1990). With a GIS it is possible to examine a host of realistic decision-making scenarios, from solid-waste disposal to location of schools and fire stations, zoning, land use decisions, and evaluation of development plans (Goodchild and Palladino 1995). When decisions are made based on GIS analysis, one should not only consider the validity of the decision formulated, but also the accuracy of the data used to derive the decision. Because these decisions directly affect the public, making sure that the highest quality data is used for decision-making may be the most important step in any decision-making process.

A GIS can model surfaces in three general ways: as contour lines or isolines, as a triangulated irregular network (TIN), or as a raster surface (Zeiler 1999). An example of a dataset that uses contour lines to enhance surface visualization is a United States Geological Survey’s (USGS) quadrangle map. Triangulated irregular networks consist of vector data that partition geographic space into contiguous, non-overlapping triangles such that the vertices of each triangle are data points with x, y, and z values (Kennedy 2001). A surface raster is a spatial data model made of rows and columns of cells where each cell contains an attribute value and location coordinates that are contained in the ordering of the matrix. An example of a surface raster is the DEM data product produced by the USGS (Weih and Smith 1996). Raster surfaces are the most common representations of surfaces because elevation data is widely available in this format (Zeiler 1999).

With the increased availability of DEMs and the advancement of computerized terrain analysis tools, it is possible to quantify the topographic attributes of a landscape (Gallant and Wilson 1996). Digital elevation models are 2-D representations that describe elevations of the earth’s surface, and through manipulation in a GIS, they may be converted into 2.5-D representations to enhance visualization. From these DEMs, calculations such as slope and aspect may be modeled. The resolution of the DEM and the accuracy

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affects the results of these models (Weih and Mattson 2004). With the increased use of DEMs in GISs for decision-making, the accuracy of the data is an important issue that should be examined. All published maps and datasets produced by the USGS must adhere to the National Map Accuracy Standards (United States Geological Survey 2010). Even though USGS DEMs adhere to the National Map Accuracy Standards, one must realize that errors do exist in the datasets and must be examined to realize the limitations of the information obtained from the datasets and the magnitude of these errors. The objective of this study was to determine if a significant difference exists and to quantify the differences between GPS field elevations taken with survey grade Global Position System (GPS) units and elevations obtain from the Arkansas 5-meter DEM created in 2006.

Materials and Methods

Study Sites

Because topographic surface roughness may affect the accuracy of DEMs, three physiographic regions with a wide variation of terrain characteristics were chosen for the study. The variation in topographic relief provided a means to determine how different gradients of terrain variation affected the vertical accuracy in DEMs. The physiographic regions were the Boston Mountains, the Ouachita Mountains, and the Mississippi Alluvial Plain. Figure 1 shows the location of the three physiographic regions in Arkansas. In each physiographic region, three study sites were selected, each in an individual USGS quadrangle. Each study site is approximately 4.8 x 4.8 km in area consisting of approximately 2,330 hectares. In summary, there were three physiographic regions, each having three study sites, or nine study sites sampled.

The Boston Mountains province covers the northwestern corner of Arkansas. This physiographic region covers an area of 103,599 sq. km and includes parts of four states: Arkansas, Kansas, Missouri, and Oklahoma (U.S. Department of Agriculture, Forest Service 1999). The most striking feature of the Boston Mountains is the rugged topography, which consists of flat-topped mountains that are more than 610 meters higher than the lowlands of the southern half of the state (Foti and Hanson 1992). This highly variable landscape was intended to describe how DEMs respond to areas of significant elevation changes over short distances. The Boston Mountains study sites were in the Oark, Boston, and Ozone quadrangles.

The second region is located in the Ouachita Mountains, which is south of the Boston Mountains. Although this area is considered a mountainous region, the topography is considerably different from the Boston Mountains in respect to landform. While the Boston Mountains have flat-topped mountains, the Ouachita Mountains consist of long, narrow ridges running from east to west (Foti and Hanson 1992). Altitudes of land in the Ouachita Mountains range from less than 91 meters to more than 838 meters above sea level. This region was intended to reveal how DEMs respond to areas of intermediate and constant elevation. The Ouachita Mountains study sites were in the Jessieville, Nimrod SE, and Paron SW quadrangles.

The third region was located in the Mississippi Alluvial Plain. This area, when compared with the previous two, consists of gently rolling hills to flat bottomlands (Foti and Hanson 1992). Because this area has small elevation differences, it was intended to answer how DEMs respond to areas of low and constant elevation over large distances. The Mississippi Alluvial Plain study sites were in the Winchester, Kelso, and McArther quadrangles.

Digital Elevation Model

The Arkansas 5-meter DEM used in this study was collected as an ancillary product of a statewide orthophoto acquisition using a Lecia ADS40 digital pushbroom sensor. EarthData International processed the data. The coordinate system used was Universal Transverse Mercator projection (UTM) on the North American Datum of 1983 (NAD83). The aerial imagery acquired between January 15 and March 31,
Assessing the Vertical Accuracy of Arkansas Five-Meter Digital Elevation Model for Different Physiographic Regions

2006 was used to create the 5-meter DEM. EarthData processed a Digital Surface Model (DSM) dataset to identify and remove the majority of elevation points falling on vegetation, buildings, and other above ground structures to generate the 5-meter Digital Terrain Model (DTM) or Digital Elevation Model (DEM) as referenced in this study.

Ground Elevation Sampling

Since accurate elevation measurements were needed to determine the accuracy of the DEM datasets, the study sites were sampled with survey grade Global Positioning Systems (GPS). Dual-frequency carrier phase GPS was chosen rather than mapping-grade GPS due to inaccuracies of mapping-grade GPS in determining elevation. Dual-frequency GPS can model and remove not all, but a significant portion of the ionosphere bias, and it is not affected by selective availability because actual phase measurements are used for the GPS measurements (Van Sickle 2001).

These measurements allowed comparisons to be made between the elevations of the observed field point positions and the corresponding locations found in the DEM. For this study, a post-processed, fast static survey using Trimble Model 4700 GPS receivers in combination with a Micro Centered L1/L2 antenna, and a TCSI data collector was used. The data was processed to determine the horizontal position and vertical elevation of all ground control points. All horizontal GPS measurements were converted to Universal Transverse Mercator (UTM) coordinates and elevation data converted to topographic surface elevation represented in meters. This was assumed the true location and elevation for this study. A minimum of 90 sample points were collected per physiographic region, meaning there were approximately 30 sample points per study site. All GPS observations were located at least 100 meters from any other sample point. The Survey GPS elevation values were considered the true elevation for each location.

Results

A paired t-test was used to determine if there was a significant difference between DEM elevation values and true elevation values. A significance level of $\alpha = 0.05$ was used for tests in this study. The absolute elevation difference value was tested. However, inferences about the magnitude of elevation error in relation to overestimation and underestimation elevation difference analyses were done using paired t-tests. Tests were performed for each physiographic region (global basis), per physiographic region (regional basis), and per study site (study site basis). This approach was used instead of using the root mean square error so comparisons could be made with the mean difference.

The AMRV measurement allowed the absolute mean elevation difference found for each DEM dataset to be normalized relative to the range of true elevation values so that comparisons could be made between physiographic region datasets. It was assumed that a population with a large range of true elevation values tended to have a larger absolute mean difference (AMD) value due to the variability in the population. However, this does not necessarily mean that datasets with smaller absolute mean elevation differences have less error.

The following formula was used for AMRV:

$$AMRV = \left( \frac{AMD}{Range} \right) (100\%) \quad (1)$$

where:

$AMD$ = the absolute mean difference computed by subtracting true elevation values from the 5-meter DEM elevation values and calculating the mean of the absolute value difference

$Range$ = the difference between the maximum and minimum true elevation values in the study area

$AMRV$ = absolute mean range value.

When true elevation values were subtracted from corresponding 5-meter DEMs to determine absolute elevation difference on a global basis, statistically (Table 1) there was a difference in elevation. The mean absolute difference determined on a global basis was 2.899 meters (Table 2). Mean absolute differences found on a regional basis varied. The mean absolute difference for the Mississippi Alluvial Plain was found to be quite small (1.057 meters) when compared to the Boston Mountains (4.976 meters) and Ouachita Mountains (2.807), on average, had larger mean absolute differences (Table 2). Study sites in the Ouachita Mountains, except Paron SW, had less mean
Table 1 Comparison of true elevation values and 5-meter DEM elevation values

<table>
<thead>
<tr>
<th>Area</th>
<th>Number of Samples</th>
<th>t-value</th>
<th>p</th>
<th>True Difference</th>
<th>t-value</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combined physiographic entities</td>
<td>303</td>
<td>13.887</td>
<td>&lt;0.0001</td>
<td>-0.326</td>
<td>0.7445</td>
<td></td>
</tr>
<tr>
<td>Boston Mountains</td>
<td>96</td>
<td>9.850</td>
<td>&lt;0.0001</td>
<td>-1.900</td>
<td>0.0605</td>
<td></td>
</tr>
<tr>
<td>Ouachita Mountains</td>
<td>104</td>
<td>10.335</td>
<td>&lt;0.0001</td>
<td>3.426</td>
<td>0.0009</td>
<td>*</td>
</tr>
<tr>
<td>Mississippi Alluvial Plain</td>
<td>103</td>
<td>10.504</td>
<td>&lt;0.0001</td>
<td>-1.954</td>
<td>0.0534</td>
<td></td>
</tr>
<tr>
<td>Oark</td>
<td>33</td>
<td>6.749</td>
<td>&lt;0.0001</td>
<td>-0.200</td>
<td>0.8425</td>
<td></td>
</tr>
<tr>
<td>Boston</td>
<td>31</td>
<td>5.963</td>
<td>&lt;0.0001</td>
<td>0.550</td>
<td>0.5863</td>
<td></td>
</tr>
<tr>
<td>Ozone</td>
<td>32</td>
<td>5.780</td>
<td>&lt;0.0001</td>
<td>-2.866</td>
<td>0.0074</td>
<td>*</td>
</tr>
<tr>
<td>Jessieville</td>
<td>34</td>
<td>5.012</td>
<td>&lt;0.0001</td>
<td>-0.847</td>
<td>0.4029</td>
<td></td>
</tr>
<tr>
<td>Nimrod SE</td>
<td>31</td>
<td>6.463</td>
<td>&lt;0.0001</td>
<td>1.738</td>
<td>0.0925</td>
<td></td>
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<tr>
<td>Paron SW</td>
<td>39</td>
<td>8.454</td>
<td>&lt;0.0001</td>
<td>-3.940</td>
<td>0.0003</td>
<td>*</td>
</tr>
<tr>
<td>Winchester</td>
<td>39</td>
<td>7.254</td>
<td>&lt;0.0001</td>
<td>-2.193</td>
<td>0.0345</td>
<td></td>
</tr>
<tr>
<td>Kelsa</td>
<td>34</td>
<td>8.346</td>
<td>&lt;0.0001</td>
<td>6.708</td>
<td>0.0007</td>
<td></td>
</tr>
<tr>
<td>McArthur</td>
<td>30</td>
<td>6.751</td>
<td>&lt;0.0001</td>
<td>-3.778</td>
<td>0.0007</td>
<td></td>
</tr>
</tbody>
</table>

1 Absolute differences were computed by subtracting true elevation values from corresponding 5-meter DEM elevation values and taking the absolute value
2 True differences were computed by subtracting true elevation values from corresponding 5-meter DEM elevation values
* Significantly different at $\alpha = 0.05$

absOLUTE differences when compared to the Boston Mountains (Table 2). Study sites in the Mississippi Alluvial Plain had a mean absolute difference less than one meter except for Winchester.

Based on the results found by performing an elevation error magnitude analysis on the true elevation difference, it was found that 5-meter DEMs underestimated elevations for the Mississippi Alluvial Plain and Boston Mountains while overestimating elevations for the Ouachita Mountains.

Absolute mean range value (AMRV) was computed on a global, regional, and per study site (Table 2). On a regional basis, the AMRV was consistently higher for the Mississippi Alluvial Plain in comparison to the other physiographic regions, with AMRV being similar for the Boston and Ouachita Mountains (Table 2). This same trend was also found on a per study site basis.

**Discussion and Conclusions**

The 5-meter DEM statistically did not accurately model surface elevations for all the study areas when considering just absolute elevation value differences (Table 1). Examining just the elevation differences, elevation was underestimated by the 5-meter DEM except for the Ouachita Mountains. The reason the Ouachita Mountains were overestimated could be that the 5-meter DEM was created photogrammetrically and the conifer trees were not effectively removed from the DEM. This physiographic region had a higher density of pine trees than the other regions.

The objective of this study was not only to examine accuracy, but also to examine the magnitude of the errors. One can expect to be within mean absolute elevation difference of $2.90 \pm 0.41$ meters statewide using the 5-meter DEM (Table 3). The error will be highest in the Boston Mountains ($4.98 \pm 1.00$ meters) and lowest in the Mississippi Alluvial Plain ($1.06 \pm 0.41$ meters). Even though the lower error was in the Mississippi Alluvial Plain, the magnitude of the error will be greater with an AMRV of 12.421% (Table 2). A substantial amount of elevation error existed in a smaller range of true elevation values. It was observed that as variability in topographic elevation increased, error in the 5-meter DEM elevation values also increased.

This hypothesis was also supported in a study performed by Isaacson and Ripple (1990). They compared only 30- and 100-meter DEMs for the Echo Mountain SE quadrangle in the Cascade Mountains of Oregon. Isaacson and Ripple (1990) calculated the mean elevation difference between 100- and 30-meter DEMs for their entire study area was 31 meters. They also stated most of the higher differences appeared to be associated with steeper slopes.

It has been emphasized that the use of accurate data must be the most important function in the decision-making process. This study demonstrated that 5-meter DEM has different magnitudes of elevation differences when compared to the Boston Mountains (Table 2). Study sites in the Mississippi Alluvial Plain had a mean absolute difference less than one meter except for Winchester.
Table 2. Mean, minimum, and maximum attributes for absolute and true differences for 5-meter DEM

<table>
<thead>
<tr>
<th>Area</th>
<th>Absolute Difference</th>
<th>AMRV</th>
<th>True Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (meters)</td>
<td>Min</td>
<td>Max</td>
</tr>
<tr>
<td>Combined physiographic</td>
<td>2.899</td>
<td>0.021</td>
<td>33.621</td>
</tr>
<tr>
<td>entities</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boston Mountains</td>
<td>4.976</td>
<td>0.200</td>
<td>33.621</td>
</tr>
<tr>
<td>Ouachita Mountains</td>
<td>2.807</td>
<td>0.067</td>
<td>12.203</td>
</tr>
<tr>
<td>Mississippi Alluvial Plain</td>
<td>1.057</td>
<td>0.021</td>
<td>5.318</td>
</tr>
<tr>
<td>Oark</td>
<td>4.739</td>
<td>0.695</td>
<td>18.189</td>
</tr>
<tr>
<td>Boston</td>
<td>3.465</td>
<td>0.200</td>
<td>15.197</td>
</tr>
<tr>
<td>Ozone</td>
<td>6.684</td>
<td>0.613</td>
<td>33.621</td>
</tr>
<tr>
<td>Jessievile</td>
<td>1.507</td>
<td>0.067</td>
<td>5.318</td>
</tr>
<tr>
<td>Nimrod SE</td>
<td>2.176</td>
<td>0.078</td>
<td>8.531</td>
</tr>
<tr>
<td>Paron SW</td>
<td>4.443</td>
<td>0.184</td>
<td>12.203</td>
</tr>
<tr>
<td>Winchester</td>
<td>1.539</td>
<td>0.071</td>
<td>5.318</td>
</tr>
<tr>
<td>Kelso</td>
<td>0.596</td>
<td>0.034</td>
<td>1.608</td>
</tr>
<tr>
<td>McArthur</td>
<td>0.952</td>
<td>0.021</td>
<td>2.615</td>
</tr>
</tbody>
</table>

1 Absolute difference were computed by subtracting true elevation values from corresponding 5-meter DEM elevation values and taking the absolute value
2 AMRV represents the absolute mean range value
3 True differences were computed by subtracting true elevation values from corresponding 5-meter DEM elevation values

error. Even though errors exist in this DEM, scientists and decision-makers must realize these datasets are important, and must consider the trade-offs when choosing datasets of higher accuracies. Even though the 5-meter DEM did not statistically represent the true elevation surface, it is still a valuable data set. It is currently the highest spatial resolution DEM available for the state of Arkansas.

Table 3. Comparison of 95% confidence intervals of the mean absolute elevation differences.

<table>
<thead>
<tr>
<th>Area</th>
<th>95% Confidence Interval (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combined physiographic</td>
<td>2.90 ± 0.41</td>
</tr>
<tr>
<td>entities</td>
<td></td>
</tr>
<tr>
<td>Mississippi Alluvial Plain</td>
<td>1.06 ± 0.20</td>
</tr>
<tr>
<td>Ouachita Mountains</td>
<td>2.81 ± 0.54</td>
</tr>
<tr>
<td>Boston Mountains</td>
<td>4.98 ± 1.00</td>
</tr>
</tbody>
</table>

Acknowledgments

This project would not have been possible without the help of many people. Special thanks to David General, Alan Procell, and David Dickson for collecting the GPS data. Also, thanks to the Arkansas Forest Resources Center and the School of Forest Resources at the University of Arkansas at Monticello for its support of this study.

Literature Cited


Detection of Inositol Polyphosphates by Polyacrylamide Gel Electrophoresis (PAGE) under Apoptotic Conditions in Cultured SW480 Cells


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Abstract

Inositol phosphates are naturally occurring compounds that regulate diverse cellular processes including apoptosis. Apoptosis is a mechanism by which cells undergo natural death to maintain cellular homeostasis. It causes cell death in areas during a state that is harmful to the body. It also regulates cellular development. Previous work has shown that exogenously administered, as well as endogenously manipulated inositol phosphates bring about apoptotic changes. It has been demonstrated that cellular levels of inositol phosphates, particularly higher inositol phosphates such as inositol hexakis-phosphate (IP$_6$) and diphosphoinositol pentakis-phosphate (IP$_7$) levels increase during apoptotic conditions. In this study, we have attempted to separate and identify higher inositol phosphates such as IP$_6$ by polyacrylamide gel electrophoresis (PAGE) and shown that changes in inositol phosphate levels can be detected by this method. Cells were treated with etoposide to induce apoptosis, and apoptotic cells were observed under UV light following ethidium bromide/acridine orange staining. This staining showed that IP$_3$ - IP$_6$ induced apoptosis in SW480 cells with IP$_6$ being the most effective inducing agent. The extracts from apoptotic and control cells were then loaded onto the polyacrylamide gel and run along with standard IP$_6$. Results showed that IP$_6$ could be detected using the PAGE method and that cellular levels of IP$_6$ were increased in SW480 cells, in which apoptosis had been induced by etoposide. Our results demonstrated that this technique could be utilized instead of the laborious radioactive labeling and HPLC separation method to study the changes in cellular levels of inositol phosphates particularly IP$_6$.

Introduction

Cancer research over the past decade has been a growing field. It is necessary to promote longevity for those in need of cancer treatments. Cancer treatments begin their journey in a lab, as researchers experiment with cells using different methods to find cures. Firstly, it is important to understand how normal and abnormal cells differ. A normal cell in the human body reproduces through regulated signals, and when cultured, or grown in the lab for research, they stop dividing once they carpet the bottom of the flask, a process known as contact inhibition. They are also characterized as having a function. Tumor cells on the other hand, do not stop dividing even when they cover the bottom of a flask, i.e. they do not exhibit contact inhibition. Instead, they continue to grow, and it can be assumed that they do not possess signaling cells like normal cells. They also do not appear the same as normal cells, and since structure corresponds with function, if the shape has been modified compared to that of a normal cell, one can assumes that the cell is abnormal, and is harmful to the body. Normal cells perform specific functions in the body, however, abnormal cells do not have special functions to perform, and therefore they lack normal shape. The majority of cancer related deaths are due to the spread of cancer cells from their primary site to other parts of the body. Treatments aimed at specifically inducing apoptosis in cancerous cells should greatly reduce the number of cancer related deaths. Ideally, to see if the treatments applied to the cells have any effect i.e. the cells should reach a high percentage of apoptosis. Apoptosis is a technical term for cell suicide. In apoptosis “the cell surface is altered, displaying properties that cause the dying cell to be rapidly phagocytosed, either by a neighboring cell or by a macrophage” (Alberts et. al. 2002). The use of signaling mechanisms with metabolic intermediates such as inositol phosphates can help increase the amount of apoptosis. We have previously shown that extracellular administration of IP$_4$, IP$_5$, and IP$_6$ increased apoptosis in a dose-dependent manner (Agarwal et al. 2009).

Inositol phosphates are a group of six-carbon...
carbohydrates that are phosphorylated and found in nature and have important roles in intracellular communication (Turner et al 2002). In mammalian cells, they play important signaling roles in regulating diverse cellular processes including vesicular trafficking and apoptosis (Berridge et. al 1989). Previous experiments have shown that IP 4,6 greatly impact apoptotic behavior. The same is true of the common chemotherapy drug etoposide, Etoposide is a chemotherapeutic medicine that can be administered orally or intraperitoneal. Etoposide is an inhibitor of the enzyme Topoisomerase II and is used as a form of chemotherapy in combination with other drugs. It breaks the genetic material inside the cancer cells and prevents them from further increasing in number, and then eventually the cells die.

Analysis of inositol phosphates has suffered greatly from the lack of simplified detection techniques. Although, the high-performance liquid chromatographic (HPLC) method has allowed mass analysis of inositol phosphates from cells and tissues (Guse et al 1995), this method is still insensitive, laborious and gives an under-estimation of the inositol phosphates. Other methods use radioactive precursors to label metabolically active cells and tissues in order to detect higher inositol phosphates, but the use of radioactivity is hazardous and also expensive. Therefore, Saiardi and colleagues developed a new method of detection of inositol phosphates. The rapid and simple method for the analysis makes use of polyacrylamide gel electrophoresis (PAGE) with toluidine blue staining in order to visualize IP 6 and DAPI staining for IP 7. Although Saiardi and colleagues originally used standard inositol phosphates for their research, their results suggest that this method can be used to determine levels of inositol phosphates under cellular processes such as apoptosis. Therefore, in this manuscript, we report the use of this PAGE method to examine whether levels of IP 6 in SW480 colorectal cancer cells change following induction of apoptosis by etoposide.

Materials and Methods

Cell Culture

Using standard sterile techniques, SW480 colorectal cancer cells were maintained in flasks containing 12ml DMEM media with 10% fetal bovine serum (FBS) at 37°C. Once cells reached confluency, they were plated in 6-well plates at a density of 5 x 10⁴ cells per well and incubated at 37°C for 24 h. The media was then replaced with starvation media (DMEM with 2% FBS) and cells left in the incubator at 37°C for 24 hours.

Induction of Apoptosis

Apoptosis was induced by adding etoposide [100nM] or inositol phosphates (IP 3-6) [100μM] in experimental samples. DMSO and H 2O were used as vehicle controls for etoposide and inositol phosphates respectively. The cells were then incubated overnight. Media were removed from the cells and the cells were washed with 1X PBS, pH 7.4. The cells were either lysed with lysis buffer (Agarwal et al 2009) for electrophoresis or stained with acridine orange and ethidium bromide for visualization under microscope and determination of the extent of apoptosis.

Acridine Orange/Ethidium Bromide Staining

Cells were washed with 1X PBS and then stained with a solution containing equal volumes of 100 mg/ml acridine orange and 100 mg/ml ethidium bromide. Cells were observed under U.V light using Nikon fluorescence microscope fitted with a digital camera. Live (green) and apoptotic (orange) cells were counted (Agarwal et. al 2009) for determining the percent apoptosis. Approximately 200-300 cells were counted for each treatment. Results are expressed as means ±SE from three independent experiments. Student’s “t” test and one way ANOVA was to determine significance. Statistical significance was defined as

Preparing Cell Extract

The cells were washed with 1X PBS after the media was removed. 100μl of lysis buffer was added to culture dishes to extract total inositol phosphates. The cells were scrubbed and left on ice for 15min. The solution was then transferred to 2ml Eppendorf tubes and centrifuged at 4°C, 18,000xg for 10 min. The supernatant was collected and used for gel electrophoresis.

Polyacrylamide Gel Electrophoresis

The samples were run on a 33% polyacrylamide mini gel (7.925 ml of 40% Acryl/Bis 19:1, 0.95ml of 10X TBE, 0.55ml of dH 2O, 67.5μl of 10% APS, 7.5 μl of TEMED), for almost 3 hours or until the dye front reached 2/3rd of the gel length. The samples were mixed with Blue/Orange Loading 6X Dye [0.4% orange G, 0.03% bromophenol blue, 0.03% xylene cyanol FF, 15% Ficoll 400, 10mM Tris-HCl (pH 7.5) and 50mM EDTA (pH 8.0)] prior to loading onto the gel (Saiardi et. al 2009).

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Toluidine Blue Staining

The gel was agitated for 30 min in a filtered staining solution (20% methanol, 2% glycerol, 0.05% Toluidine Blue), and then destained for 2 hours with several changes of the same solution without the dye. Pictures were taken after exposing the gel to a white light transilluminator using BioRAD Gel Documentation System.

Results

After apoptosis was induced in the 6-well plates, cells were stained with acridine orange/ethidium bromide and photographs were taken to see the effects of the different treatments on apoptosis. The acridine orange/ethidium bromide staining indicated that different treatment agents had different apoptotic potentials which can be seen in Figure 1.

Quantitative data based on the results in Figure 1 is shown in Figure 2. Etoposide used as positive control induced most apoptosis as has been previously established in our lab (Rakhee et al 2009). In addition, it can also be seen that IP6 induces more apoptosis than any other inositol phosphates tested.

In order to detect inositol phosphates on PAGE, different IP standards measuring 15nmol each of IP4, IP5, IP6, and IP7 were run on the 33% polyacrylamide gel. As shown in Figure 3, we can clearly see that IP6 was detected when the gel was observed under the white light transilluminator after staining with toluidine blue. However, IP4, IP5, and IP7 were not detected. Toluidine blue staining could only detect IP6 on PAGE under experimental conditions stated in this method. Other experimental conditions and staining procedures may be required to visualize other inositol phosphates on the gel.

Figure 2: The quantitative analysis of results from Figure 1. Etoposide showed the most apoptotic activity. IP6 was most effective among all inositol phosphates.

Figure 3: Detection of inositol phosphates (IP4, IP5, IP6, IP7) standards along with 6x dye were loaded on the 33% gel. We can see the dye front and also the detection of IP6.

Figure 4: Detection of IP6 by PAGE. Different amounts of IP6 ranging from 1.0 nmol to 15.0 nmol were mixed with the 6x dye and loaded onto the gel. Following electrophoresis, gel was stained with toluidine blue. Arrow indicates the position of IP6. Intensity of IP6 band increases with amount loaded.
Since IP₆ is detectable by this procedure, we wondered whether the detection of IP₆ was concentration dependent. Therefore different amounts of IP₆ were prepared, mixed with loading dye and run on a 33 % acrylamide gel. Six different amounts were prepared ranging from 1.0 nmol to 15 nmol. Figure 4 shows that IP₆ was separated and the detection was concentration dependent. Densitometry analysis showed that there was a linear relationship between the concentration of IP₆ and the density of the bands observed (Figure 5).

To determine if changes in inositol phosphates levels during apoptosis could be detected, cell extracts from control cells and etoposide-induced apoptotic cells from duplicate samples were prepared and run on the gel along with IP₆ standard. Samples containing extracts or 15 nmol of IP₆ standards were prepared and analyzed as detailed above. Figure 6 shows that no IP₆ was detected in the control cells while apoptotic cells showed the presence of IP₆. We assumed that this band represents IP₆ based on its relative migration on the gel with standard IP₆. Further experiments to hydrolyze the cell extracts with phytase would confirm the identity of this band as IP₆.

**Discussion**

Inositol phosphates have attracted increased attention for their possible roles as signaling molecules and a wide range of biological functions (Berridge et. al 1989). Similarly, important human diseases such as cancer and diabetes appear to be under regulation by inositol phosphates (Nagata et al, 2005). However, significantly more research is needed to discover the full mechanisms controlled by these signaling molecules. The objective of this study was to examine whether we could detect any changes in IP₆ during apoptosis. According to our results, IP₆ was easily detected compared to other inositol phosphates but the possibility of their detection using PAGE method cannot be ruled out. For example, using the 6x Orange G dye and DAPI staining could possibly enable the detection of IP₇. Alternatively more sensitive detection techniques might help visualize the presence of higher inositol phosphates (IP₇). As far as IP₆ is concerned, the PAGE method used proved to be useful for quantitative analysis of IP₆. Furthermore, under apoptotic conditions, IP₆ levels increased and were detectable by this method.

**Literature cited**


Detection of Inositol Polyphosphates by PAGE Under Apoptotic Conditions in Cultured SW480 Cells


Molecular Structure of fac-Aquadichlorotris(dimethylsulfoxide)ruthenium(II)

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²Crystallographic Systems, Bruker AXS Inc., 5465 East Cheryl Parkway, Madison, WI 53711 USA

¹Correspondence: mdraganj@astate.edu

Chiannelli has studied a series of transition-metal sulfides for their ability to catalytically hydrodesulfurize (HDS) dibenzothiophene, with RuS₂ showing greatest activity (Pecoraro and Chiannelli 1981). Numerous thiophene compounds have been prepared to model the HDS active site. Of these compounds, none have a coordination sphere consisting entirely of sulfur ligands (Angelici 1990, Rauchfuss 1991). In an attempt to prepare model compounds that more closely resemble the RuS₂ active site for the HDS process, Ru(dmso)₄Cl₂ was chosen as the starting material due to its versatility in the synthesis of a variety of ruthenium(II) complexes (Evans et al. 1973).

Replacement of the chloride ligands by the potentially chelating CS₃²⁻ moiety was attempted by reacting equimolar amounts of Ru(dmso)₄Cl₂ and K₂CS₃ in CH₂Cl₂ under air. After filtration and upon crystallization from CH₂Cl₂/hexanes, yellow crystals were obtained in small yield. The yellow crystals were analyzed using single-crystal x-ray diffraction techniques, and were determined to be fac-aquadichlorotris(dimethylsulfoxide)ruthenium(II), I.

A yellow crystal of I with the dimensions of 0.20 mm x 0.20 mm x 0.40 mm was mounted on a Mitegen Micromount and was automatically centered on a Bruker SMART X2S benchtop crystallographic system. Data were acquired using three sets of Omega scans at different Phi settings. The frame width was 0.5°, with an exposure time of 5.0 s. Crystal data are given in Table 1.

The compound fac-[Ru(dmso)₃(OH₂)Cl₂] forms rapidly when Ru(dmso)₄Cl₂ is placed in H₂O (Barnes and Goodfellow 1979, Alessio et al. 1988). Though compound I has been characterized spectroscopically by ¹H NMR (Barnes and Goodfellow 1979), photochemically (Brindell et al. 2007), and investigated for anticancer activity (Brindell et al. 2005), the single-crystal structure had not been determined.

Compound I crystallizes with two molecules in the symmetric unit. A 1/8 water of hydration was also observed. The structure of I is seen in Figure 1. The dmso ligands are in the facial configuration, with two of the dmso ligands trans to the chloride ligands and the other trans to the H₂O ligand. All of the dmso ligands are S-bound. Selected bond distances are given in Table 2.

Table 1. Crystallographic data for fac-Ru(dmso)₃(OH₂)Cl₂·1/8 H₂O.

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formula</td>
<td>C₁₂H₄₀.2₅Cl₆O₈.1₂₅Ru₂S₆</td>
</tr>
<tr>
<td>Formula weight (amu)</td>
<td>851.04</td>
</tr>
<tr>
<td>Temperature (K)</td>
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<tr>
<td>Unit cell dimensions</td>
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</tr>
<tr>
<td>a (Å)</td>
<td>15.289(11)</td>
</tr>
<tr>
<td>b (Å)</td>
<td>7.899(5)</td>
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<tr>
<td>c (Å)</td>
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</tr>
<tr>
<td>α (°)</td>
<td>90</td>
</tr>
<tr>
<td>β (°)</td>
<td>90.131(2)</td>
</tr>
<tr>
<td>γ (°)</td>
<td>90</td>
</tr>
<tr>
<td>V (Å³)</td>
<td>5984.6(8)</td>
</tr>
<tr>
<td>Dcalc (Mg/cm³)</td>
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</tr>
<tr>
<td>Space group</td>
<td>monoclinic C2/c</td>
</tr>
<tr>
<td>Z</td>
<td>8</td>
</tr>
<tr>
<td>F(000)</td>
<td>3434</td>
</tr>
<tr>
<td>λ (Å)</td>
<td>0.71073</td>
</tr>
<tr>
<td>μ (mm⁻¹)</td>
<td>1.819</td>
</tr>
<tr>
<td>2θ range (°)</td>
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</tr>
<tr>
<td>Absorption correction</td>
<td>Multiscan</td>
</tr>
<tr>
<td>Total reflections</td>
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</tr>
<tr>
<td>Unique reflections</td>
<td>5283</td>
</tr>
<tr>
<td>R for merge</td>
<td>0.0554</td>
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<tr>
<td>Data for refinement</td>
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</tr>
<tr>
<td>Parameters</td>
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</tr>
<tr>
<td>Final R [I&gt;2sigma(I)]</td>
<td>R₁ = 0.322</td>
</tr>
<tr>
<td></td>
<td>wR₁ = 0.0589</td>
</tr>
<tr>
<td>R indices (all data)</td>
<td>R₁ = 0.0405</td>
</tr>
<tr>
<td></td>
<td>wR₁ = 0.0613</td>
</tr>
<tr>
<td>GOF</td>
<td>1.077</td>
</tr>
<tr>
<td>Largest diff. peak and hole</td>
<td>0.507, -0.413</td>
</tr>
</tbody>
</table>

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https://scholarworks.uark.edu/jaas/vol64/iss1/1

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Table 2. Selected bond distances (Å) for I.

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Ru1-O1</td>
<td>2.158(3)</td>
<td></td>
</tr>
<tr>
<td>Ru2-O5</td>
<td>2.153(3)</td>
<td></td>
</tr>
<tr>
<td>Ru1-S1</td>
<td>2.2650(10)</td>
<td></td>
</tr>
<tr>
<td>Ru2-S4</td>
<td>2.2801(9)</td>
<td></td>
</tr>
<tr>
<td>Ru1-S2</td>
<td>2.2790(10)</td>
<td></td>
</tr>
<tr>
<td>Ru2-S5</td>
<td>2.2595(10)</td>
<td></td>
</tr>
<tr>
<td>Ru1-S3</td>
<td>2.2412(9)</td>
<td></td>
</tr>
<tr>
<td>Ru2-S6</td>
<td>2.2467(10)</td>
<td></td>
</tr>
<tr>
<td>Ru1-Cl1</td>
<td>2.4433(10)</td>
<td></td>
</tr>
<tr>
<td>Ru2-Cl3</td>
<td>2.4269(10)</td>
<td></td>
</tr>
<tr>
<td>Ru1-Cl2</td>
<td>2.24095(10)</td>
<td></td>
</tr>
</tbody>
</table>

The Ru-S bond distances for the dmso ligands trans to the chlorides are longer than the Ru-S distance for the dmso trans to the water molecule. This is consistent with the observed bond distances for the sulfur-bound dmso ligands in Ru(dmso)₄Cl₂. The Ru-S distance for the dmso trans to the O-bound dmso is 2.245(1) Å as compared to 2.274(1) and 2.284(1) Å for the Ru-S distances for the dmso ligands trans to chloride (Alessio et al. 1988).

Though the isolation of crystals of compound I was serendipitous, a new structure was obtained. Further reactions of Ru(dmso)₄Cl₂ with K₂CS₃ under nitrogen will be investigated.

**Supplemental Materials**

Supplemental materials are available from the authors upon request.

**Acknowledgments**

The authors thank Arkansas State University and the Department of Chemistry and Physics for their support of this project.

**Literature Cited**


Distribution of the Endemic Redspotted Stream Crayfish, Orconectes acares (Decapoda: Cambaridae), in Arkansas

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There has been a recent increase in interest in the study of the crayfishes of Arkansas (Robison and McAllister 2008, 2009, 2010; Crandall et al. 2009). Crayfishes are an important component of aquatic habitats, serving as a food source for numerous vertebrates. One of these species, the redspotted stream crayfish Orconectes (Procericambarus) acares Fitzpatrick, is a relatively small decapod that is endemic to tributaries of the Ouachita River in 7 counties of the state (Hobbs 1989). Originally described as a subspecies of Orconectes leptogonopodus by Fitzpatrick (1965), O. acares was elevated to full species by Hobbs (1972). The type locality is an unnamed tributary to the Ouachita River, 9.7 km NW of Mount Ida, Montgomery County (Fitzpatrick 1965). According to the Nature Conservancy (NatureServe 2009), O. acares is ranked G4 (apparently secure) in the state.

Between April 1996 and October 1997, March and May 2000, and again between October 2009 and April 2010, we collected O. acares in small streams in the Ouachita National Forest (ONF) of Arkansas and Oklahoma using a variety of methods, including: minnow seines, one-man seines, backpack electroshockers, aquatic dipnets, baited and unbaited crayfish traps, or overturning rocks by hand. Select voucher specimens were preserved in 60% isopropanol and deposited in the Southern Arkansas University (SAU) Invertebrate Collection and the Smithsonian National Museum of Natural History (USNM) Invertebrate Zoology Collection in Washington, D.C. In addition, to document previously unpublished records of O. acares, we searched 3 of the larger online museum databases, including the Illinois Natural History Crustacean Collection, University of Illinois at Urbana-Champaign (INHS), the North Carolina State Museum of Natural Sciences Crustacean Collection, Raleigh (NCSM), and the USNM. All previous literature dealing with O. acares was reviewed and distributional information was utilized when deemed accurate.

Diagnosis.—Rostrum with marginal tubercles or spines, median carina present, margins subparallel or slightly converging cephalad, not thickened. Length of areola 29.1 to 33.7% of total length (TL) of carapace, 5.5-7.0x longer than broad, 3 to 5 punctations in narrowest part. Postorbital ridges strong, divergent, corneous spines or tubercles; sides of carapace lacking lateral spines. First pleopod of first form male reaching caudal margin of coxopodite of first pereiopod with abdomen flexed; central projection with strong cephalic shoulder near base; central projection straight, longer than mesial process, setiform and straight almost to tip; mesial process, slender, with tip curving caudodistally; mesial process straight, setiform, slender, delicate; tips of first pleopod divergent and bent mesiad near tip. Chela depressed but palm somewhat inflated; all surfaces bearing setiferous punctuations.


Size.—Adults range in size from 25 to 76 mm in TL. The measurements of the carapace, areola, rostrum, and chela of the type specimens were provided by Fitzpatrick (1965).

Habitat.—Orconectes acares inhabits rapidly flowing water associated with shoals. Spring outflows are also utilized by this species.

General range.—Hobbs (1989) presented the range of O. acares as tributaries of the Ouachita River in Garland, Hot Spring, Montgomery, Perry, Pike, Polk, and Saline counties, Arkansas. It is a true Arkansas endemic (Robison et al. 2008).

Specific localities for 1,030 O. acares are listed in Table 1 and plotted in Fig. 1. Several new localities are documented as well as a new county record (Clark). Orconectes acares was found at 126 of 252 (50%) sites in Arkansas, including 81 sites in Montgomery, 18 sites in Garland, and 14 sites in Polk.
Distribution of the Endemic Redspotted Stream Crayfish, *Orconectes acares* (Decapoda: Cambaridae), in Arkansas

counties. *Orconectes acares* was collected less frequently in Clark (6 sites), Pike (3 sites), Perry (2 sites), Hot Spring (1 site) and Saline (1 site) counties (Fig. 2). Interestingly, no *O. acares* were found at any of the 204 collecting sites on the Oklahoma side (LeFlore and McCurtain counties) of the ONF. It was not found at sites on the Cossatot, Mountain Fork, Petit Jean, or Poteau rivers. This Ouachita River endemic has its distribution centered within the ONF in Garland and Montgomery counties (Fig. 1) and thus a high abundance should be expected. *Orconectes acares* was collected in all major tributaries of the Ouachita River drainage, including the Caddo, Little Missouri, Ouachita, and Saline rivers. In addition, *O. acares* was collected at several seeps and springs. Together with the western painted crayfish (*Orconectes palmeri longimanus*), *O. acares* is 1 of the 2 most abundant crayfishes in the Arkansas portion of the ONF.

Table 1. Collection sites of *O. acares* from 8 counties of Arkansas.

<table>
<thead>
<tr>
<th>County</th>
<th>Specific Locality</th>
<th>Date(s)</th>
<th>No. collected</th>
<th>Museum</th>
<th>Collector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clark</td>
<td>Wingfield Creek, 0.8 km E of St. Hwy. 53</td>
<td>8 Apr. 1974</td>
<td>10</td>
<td>USNM 145690</td>
<td>H.W. Robison</td>
</tr>
<tr>
<td></td>
<td>Caddo River at St. Hwy. 182 bridge, 2.7 km N of Amity</td>
<td>31 May 1975</td>
<td>3</td>
<td>USNM 146683</td>
<td>H.W. Robison</td>
</tr>
<tr>
<td></td>
<td>Antoine River at Graysonia (ghost town)</td>
<td>2 Aug. 1981</td>
<td>22</td>
<td>USNM 219082</td>
<td>D.D. Koym</td>
</tr>
<tr>
<td></td>
<td>Caddo River at Caddo Valley, off St. Hwy. 7 and I-30</td>
<td>27 May 1991</td>
<td>1</td>
<td>INHS 5237</td>
<td>Mayer</td>
</tr>
<tr>
<td></td>
<td>Caddo River, 4.0 km NW of Amity</td>
<td>17 May 1997</td>
<td>38</td>
<td>SAU</td>
<td>H.W. Robison</td>
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Journal of the Arkansas Academy of Science, Vol. 64, 2010
Table 1. Collection sites of *Orconectes acares* from 8 counties of Arkansas.

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<th>County</th>
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<td></td>
<td>Muddy Creek at St. Hwy. 27, S of Story</td>
<td>11 July 1996</td>
<td>2</td>
<td>SAU</td>
<td>H.W. Robison</td>
</tr>
</tbody>
</table>
## Distribution of the Endemic Redspotted Stream Crayfish, *Orconectes acares* (Decapoda: Cambaridae), in Arkansas

### Table 1. Collection sites of *Orconectes acares* from 8 counties of Arkansas.

<table>
<thead>
<tr>
<th>County</th>
<th>Specific Locality</th>
<th>Date(s)</th>
<th>No. collected</th>
<th>Museum</th>
<th>Collector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Little Missouri River</td>
<td>at FSR 22</td>
<td>3 Aug. 1996</td>
<td>3</td>
<td>SAU</td>
<td>H.W. Robison</td>
</tr>
<tr>
<td>Tea Creek (Seep)</td>
<td>Spring (T3S, R23W, Secs. 22-23)</td>
<td>27 Apr. 1996</td>
<td>16</td>
<td>INHS</td>
<td>6258 C. Taylor et al.</td>
</tr>
<tr>
<td>Ouachita River</td>
<td>at Bluff Rec. Area</td>
<td>4 June 1997</td>
<td>22</td>
<td>SAU</td>
<td>H.W. Robison</td>
</tr>
<tr>
<td>Ouachita River</td>
<td>at St. Hwy. 298</td>
<td>4 June 1997</td>
<td>15</td>
<td>SAU</td>
<td>H.W. Robison</td>
</tr>
<tr>
<td>Perry</td>
<td>Small trib., 8.9 km S of Hollis</td>
<td>23 June 1960</td>
<td>3</td>
<td>USNM</td>
<td>217145 H.W. Robison</td>
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<tr>
<td></td>
<td>on St. Hwy. 7</td>
<td>22 Apr. 2010</td>
<td>11</td>
<td>SAU</td>
<td>C.T. McAllister</td>
</tr>
<tr>
<td>Pike</td>
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<td>22 Apr. 2010</td>
<td>11</td>
<td>SAU</td>
<td>C.T. McAllister</td>
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<tr>
<td></td>
<td>off St. Hwy. 7 on FSR 780</td>
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<td></td>
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<td>Caddo River at Glenwood</td>
<td>31 May 1975</td>
<td>3</td>
<td>USNM</td>
<td>146703 H.W. Robison</td>
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<tr>
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<td>Little Missouri River</td>
<td>26 April 1996</td>
<td>1</td>
<td>SAU</td>
<td>H.W. Robison</td>
</tr>
<tr>
<td></td>
<td>at St. Hwy. 84, W of Langley</td>
<td>17 May 1997</td>
<td>1</td>
<td>SAU</td>
<td>H.W. Robison</td>
</tr>
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<td>Irons Fork Creek, near Mena</td>
<td>30 July 1997</td>
<td>4</td>
<td>USNM</td>
<td>117200 H.H. Hobbs, Jr.</td>
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<td>Shady Lake Rec. area, off St. Hwy.</td>
<td>23 Sept. 1980</td>
<td>8</td>
<td>NCSM</td>
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<td>84, 9.7 km N of Umpire</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ouachita River, 9.7 km NE of Mena</td>
<td>9 Apr. 1982</td>
<td>1</td>
<td>INHS</td>
<td>55 L.M. Page et al.</td>
</tr>
<tr>
<td></td>
<td>off St. Hwy. 71</td>
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<td></td>
<td>Ouachita River, McGuire Access,</td>
<td>28 May 1977</td>
<td>2</td>
<td>USNM</td>
<td>149024 U. Tennessee</td>
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<tr>
<td></td>
<td>between Ink and Cherry Hill</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ouachita River, 0.6 km S of Cherry</td>
<td>27 Apr. 1996</td>
<td>6</td>
<td>SAU</td>
<td>H.W. Robison</td>
</tr>
<tr>
<td></td>
<td>Hill</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>at St. Hwy. 88, 9.2 km E of Mena</td>
<td>18 May 1997</td>
<td>7</td>
<td>SAU</td>
<td>H.W. Robison</td>
</tr>
<tr>
<td></td>
<td>Roadside seepage, 15.3 km NW of Mena</td>
<td>18 May 1997</td>
<td>3</td>
<td>SAU</td>
<td>H.W. Robison</td>
</tr>
<tr>
<td></td>
<td>Ouachita River off US 71 at Acorn</td>
<td>28 Apr. 1996</td>
<td>28</td>
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<td>H.W. Robison</td>
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<tr>
<td></td>
<td>Big Fork Creek at Big Fork off St.</td>
<td>17 June 1996</td>
<td>1</td>
<td>SAU</td>
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<tr>
<td></td>
<td>Hwy. 8</td>
<td>23 June 1996</td>
<td>1</td>
<td>SAU</td>
<td>H.W. Robison</td>
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<td></td>
<td>Abernathy Springs at St. Hwy. 8</td>
<td>23 June 1996</td>
<td>3</td>
<td>SAU</td>
<td>H.W. Robison</td>
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<td></td>
<td>Big Fork Creek, 0.6 km S of Opal</td>
<td>17 June 1996</td>
<td>7</td>
<td>SAU</td>
<td>H.W. Robison</td>
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<td></td>
<td>on co. rd. 67</td>
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<td></td>
<td>Big Fork Creek at St. Hwy. 8,</td>
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<td>SAU</td>
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</tr>
<tr>
<td></td>
<td>Abernathy Springs</td>
<td>26 June 1996</td>
<td>1</td>
<td>SAU</td>
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</tr>
<tr>
<td></td>
<td>Little Missouri River</td>
<td>2 Aug. 1996</td>
<td>5</td>
<td>SAU</td>
<td>H.W. Robison</td>
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<td></td>
<td>off co. rd. 25</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Unnamed trib., 3.2 km SE of Cherry</td>
<td>18 May 1997</td>
<td>9</td>
<td>SAU</td>
<td>H.W. Robison</td>
</tr>
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<td></td>
<td>Hill</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ten Mile Creek at US 70</td>
<td>18 May 1982</td>
<td>29</td>
<td>USNM</td>
<td>178683 R.A. Etier</td>
</tr>
</tbody>
</table>

1New county record.  
2Morphotypes.  
3Holotype and allotype.

Four specimens of supposed *O. acares* deposited in the USNM (145694, 145697, 146652) from Howard County (Little River drainage) are the Little River Creek crayfish, *O. leptogonopodus*. In addition, a female crayfish reported as *O. acares* (USNM 207459) collected on an unknown date by “Lyle” from Camp Pike (=Camp J. T. Robinson Armed Forces Complex), North Little Rock, Pulaski County is also most likely another species. However, 1 of the most interesting historic collections of *O. acares* contained 3 specimens (1 form II male, 2 females) taken on 23 June 1960 from Perry County (USNM 217145), part of the Fourche LaFave River basin (Arkansas River drainage). In addition, we attempted collections of *O. acares* northward in nearby Yell County without success. We concur with Taylor et al. (2007) that
populations of *O. acares* are currently stable in the state and, at this point, require no protection. Additional attempts at collecting *O. acares* are certainly warranted, which could reveal a more extensive northerly range within the Arkansas River drainage.

**Figure 1.** Distribution of *O. acares* in the ONF of Arkansas. Dots may represent more than 1 locality since the scale of the dots cover up more than 1 collection location. Abbreviations: Clark Co. (C); Garland Co. (G); Hot Spring Co. (H); Montgomery Co. (M); Perry Co. (PE); Pike Co. (PI); Polk Co. (PO); Saline Co. (S).

**Figure 2.** Collection site (Big Hill Creek) of *O. acares* in Hot Spring County (see Table 1). Photograph by CTM on 10 September 2009.

**Acknowledgments**

We thank S. Cooper (NCSM), K. Reed (USNM), and C. Taylor (INHS) for curatorial assistance. For field assistance, we thank K. Ball, C. Carlton, N. Covington, S. Jacobs, J. T. McAllister, III, and J. Rader. The Arkansas Game and Fish Commission provided scientific collecting permits to HWR.

**Literature Cited**


New Records and Notes on the Natural History of Selected Invertebrates from Southern Arkansas

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The invertebrate fauna of southern Arkansas is less well known than that of other regions of the state, largely due to the fact that few invertebrate biologists are located in the region. The lack of expertise in identifying invertebrate species, especially larval or juvenile forms, and a lack of seasonal collecting also have limited the knowledge of species occurrence.

This report documents new records of distribution and provides notes on the natural history of selected invertebrates from southern Arkansas. Southwestern Arkansas lies almost entirely within the West Gulf Coastal Plain natural division (Foti 1974), whereas southeastern Arkansas includes part of the Mississippi Alluvial Plain.

Field observations and collections were made by the authors and students at Henderson State University (HSU) and Southern Arkansas University (SAU). Invertebrate specimens were preserved in 70% or 90% isopropanol and housed at HSU or Brigham Young University (BYU). Digital photography also was used to document species within their habitats (images available from RT).

Class Turbellaria:

_Bipalium kewense_ Moseley – land planarian. Land planarians are native to tropical Asia and have been dispersed inadvertently via the trade in tropical plants. So they are observed most commonly in greenhouses or by citizens that find these worm-like organisms in the soil of potted plants. As an invasive species, _B. kewense_ has become established across the southern United States (Ducey et al. 2007). In Arkansas, it has been reported by Daly and Darlington (1981) from the counties (cities) of Pulaski (Little Rock), Faulkner (Conway), and Ouachita (Camden).

On 12 June 2009, a specimen of _B. kewense_, representing a new county record, was collected from a landscaped area by the Reynolds Science Center at Henderson State University, Arkadelphia, Clark County, AR (Sec. 17, T7S, R19W). Another individual from the same location was photographed 10 October 2007. Custodians informed us that they commonly see these creatures on early Spring mornings after rain. Daly and Darlington (1981) also noted that _B. kewense_ was found after heavy rains on driveways in Little Rock; otherwise their specimens were discovered under wet boards, logs, rotting trees, railroad ties, and concrete patio slabs.

A single 14 cm long specimen of _B. kewense_ was collected on 14 May 1982 from the sidewalk of the HWR residence in Magnolia, AR which represents another new county record (Columbia County) for this land planarian. The sidewalk was wet from a recent rain and the worm was fully extended, displaying the diagnostic spade-like head and bi-colored body.

Class Arachnida:

_Nephila clavipes_ (Linnaeus) – the golden orbweaver, golden-silk orbweaver, or banana spider. Being a primarily neotropical genus, _Nephila clavipes_ is the only species that occurs in North America. It ranges from Central America and through the Gulf Coastal states of the United States, primarily in the warmer portions of the subtropical regions (Comstock 1948, Evans 2007). Dorris (1985) included this spider in her list of species occurring in Arkansas, but no locality data were provided and she (pers. comm.) did not remember where specimens might have been taken.

In summer of 2009, we found individuals of _N. clavipes_ in swampy habitats immediately adjacent to the Ouachita River in Ashley and Union counties of southeastern Arkansas, representing the first documented state records for the species. The initial encounter was in Union County near the Ouachita River bridge over U.S. Hwy. 82 (Sec. 18, T18S, R10W). On 10 July 2009, an adult female was photographed in the center of her web, about 1.5 m above the ground. The web was about 2 m in width.
(typical of the species, Comstock 1948) and anchored between two small oak (Quercus sp.) trees. The web was oriented to face east-west, and was located within 50 m of the river in the overflow woodlands.

On 5 September 2009, a more extensive search for N. clavipes conducted in the same area revealed 3 additional female individuals on their webs (all were photographed). One was located on a web positioned similar to the one found on 10 July, but about 40 m S of that location. The position of the webs near the ground was typical for this species. However, a second female was found positioned in the center of her web about 4 m above the ground, anchored between a red maple (Acer rubrum) and oak tree. A third female was located at an elevation of about 10 m, anchored between a muscadine (Vitis rotundifolia) vine and red maple tree.

The search was conducted between 1700-1800 hrs, and all of the spiders were found on webs facing the east-west direction. It is not known whether the spiders purposely built webs oriented in that direction, or if webs and spiders so-oriented were seen more easily. In all cases, the spiders were positioned with the venter facing westward.

Also on 5 September 2009, the Ashley County (eastern) side of the Ouachita river was searched, and 1 adult female N. clavipes was found on a typical web constructed between two small oak trees, about 1.3 m above ground. This location was only about 2 m from the river (Sec. 18, T18S, R10W).

Class Insecta:

Plecia nearctica Hardy – Nearctic love bug. The name “love bug” is due to this dipteran’s tendency to be found most commonly in breeding aggregations with many individuals in the process of mating. They are small (6-9 mm in length, males are smaller than females) black flies with a reddish thorax. At the time of its description (Hardy 1940), this fly was known to be most common in Texas and Louisiana, but Buschman (1976) documented its subsequent dispersal through the Gulf Coast states and into Florida.

Factors associated with populations include adequate moisture, decaying vegetation, and adequate exposure for favorable soil temperatures (Hetrick 1970), conditions often found in grassy habitats of pastures and along roadsides (Buschman 1976). Large aggregations of these flies along highways can become a nuisance to motorists as they splatter on windshields, and they can cause damage to automobile cooling systems by clogging radiators (Denmark et al. 2009).

An established population of Plecia nearctica was found along a power line that runs northward on the east side of Crossett, Ashley County, AR (Sec. 32, T18S, R8W). Photographs of the flies were taken at this site on 1 and 22 October 2006, and 16 May 2008, but the flies were not seen during other months. Observations of 2 emergences (spring and fall) were similar to those described for Florida, where P. nearctica is known to have 2 major emergences in April-May and August-September (Denmark et al. 2009). During the fall emergence, mating pairs were seen very commonly on goldenrods (Solidago sp.).

The present records appear to be the first report of this neotropical invader into Arkansas, and perhaps the first record in a state not bordering the Gulf or Atlantic Coasts (Denmark et al. 2009). The senior author grew up near this site and spent much of his childhood exploring the power line area, and does not recall ever seeing this insect until the last few years.

Icerya purchasi Maskell – Cottony Cushion Scale. Icerya purchasi is a scale insect commonly associated with citrus trees, although it sometimes infests fruit and shade trees and ornamentals (Peairs and Davidson 1956). It apparently was introduced into California from Australia or New Zealand about 1868 (Metcalf et al. 1962). A larger scale insect, it reaches a length of 8 mm and appears as a white mass with waxy filaments covering most of the body and a reddish-brown anterior dorsal area (Peairs and Davidson 1956).

On 6 November 2009, several specimens of I. purchasi were found by K. Benjamin on false indigo (Amorpha fruticosa L.) planted in the arboretum on the campus of Henderson State University, Clark County, AR. The original indigo plant had been collected about 4 years earlier near the banks of the Red River, growing in the vicinity of a highway overpass in Hempstead County, AR. Thus, we cannot be certain that the insect was not inadvertently transplanted from Hempstead County along with the indigo plant. The plant, collected in late October, was about 0.5 m tall when transplanted to the arboretum. Searches of other plants in the arboretum did not reveal infestations of the scale, but we did find specimens about 400 m distant on mistletoe (Phoradendron leucarpum) growing on a willow oak (Quercus phellos) tree.

The only previous Arkansas record of I. purchasi was collected from Arkansas County, AR, 16 November 1910 (apparently unpublished, housed in the University of Arkansas Arthropod Museum, Fayetteville; J. K. Barnes, pers. comm.).
Crayfish. Only 8 localities for *F. clypeata* depth. dug from burrows 36 cm (14 in.) and 53 cm (21 in.) in an aquatic dip net, whereas the other 2 specimens were temporary water situation in a roadside ditch by use of *fodiens* from Clark County were collected from a and burrows in Arkansas. The 2 specimens of be primarily an inhabitant of temporary bodies of water 1989, HWR (1 specimen – BYU). 24, T12S, R18W), Columbia County, AR, 12 April 1980, S of Whelen Springs, on AR St. Hwy. 53 (Sec. 34, T17S, R17W), Union County, AR, 21 April 1974, HWR (2 specimens - BYU).

_Faxonella clypeata_ is a secondary burrower, but all specimens collected herein were taken by aquatic dip nets from lentic bodies of water with substrates of decaying leaves. These collections include new county records for Bradley, Nevada, Ouachita, and Union counties.

*Orconectes lancifer* (Hagen) – the Shrimp Crayfish. Reimer (1963) presented only 5 localities in southern Arkansas for this species. We document 4 additional localities for *O. lancifer* from the following: (1) roadside ditch 5 km (3.1 mi.) SE of Hamburg on AR St. Hwy. 8 (Sec. 28, T17S, R6W), Ashley County, AR, 19 April 1990, HWR (3 specimens - BYU); (2) roadside ditch 8.4 km (5.2 mi.) SE of Harrell on AR St. Hwy. 160 (Sec. 4, T15S, R15W), Calhoun County, AR, 15 June 1979, HWR (7 specimens - BYU); (3) roadside ditch 1.1 km (0.7 mi.) W of Magnolia on U.S. Hwy. 82 (Sec. 34, T16S, R21W), Columbia County, AR, 26 April 1982, HWR (2 specimens - BYU); (4) flooded ditch 2.4 km (1.5 mi.) E of Strong on AR St. Hwy. 82 (Sec. 35, T18S, R17W), Union County, AR, 10 July 1993, HWR (3 specimens - BYU).

All specimens were collected with aquatip dip nets from turbid, lentic waters with mud substrates. These collections include the first county records for *O. lancifer* from Ashley, Calhoun, and Union counties.

_Procambarus ouachitae* Penn – the Ouachita River Crayfish. Reimer (1963) reported *P. ouachitae* from 11 counties in southern Arkansas. We herein report this crayfish for the first time from Bradley County: Snake Creek at Board (Sec. 30, T16S, R9W), 20 April 1984, HWR. The single specimen (BYU) was collected from a vegetated region of lentic water, by use of an aquatic dip net.
Procambarus tulanei Penn – the Giant Bearded Crayfish. Reimer (1963) reported localities for this burrower in southern Arkansas from only Columbia and Ouachita counties. Hobbs and Robison (1988) provided additional records within those 2 counties, and added new records for Ashley, Drew, Hot Spring, Jefferson, Lafayette, Montgomery, and Nevada counties. We document an additional 5 localities for Jefferson, Lafayette, Montgomery, and Nevada counties. Hobbs and Robison (1988) burrower in southern Arkansas from only Columbia Crayfish. Reimer (1963) reported localities for this Tulanei Procambarus tulanei. Some specimens of P. tulanei were taken by use of aquatic dip nets from lentic water in roadside or other small drainage ditches, and others were physically removed from burrows 28 cm (11 in.) to 68.5 cm (27 in.) deep using shovels and trowels. The Bradley and Clark County localities represent new county records for P. tulanei in Arkansas.

Acknowledgments

For technical support, we thank K. Benjamin and B. Serviss. J. K. Barnes, University of Arkansas Arthropod Museum, provided helpful information concerning records of spiders and insects.

Literature Cited


New Records and Notes on the Natural History of Selected Vertebrates from Southern Arkansas

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Tumlison et al. (1992) noted that the vertebrate fauna of southwestern Arkansas was less well known than that of other regions of the state. The same situation exists in southeastern Arkansas. Occasional papers have attempted to better document this southern Arkansas vertebrate fauna (McAllister et al. 2008, 2009, Robison and McAllister 2007, Tumlison 1992).

This report documents new records of distribution and provides notes on the natural history of selected vertebrates from southern Arkansas. Southwestern Arkansas lies almost entirely within the West Gulf Coastal Plain natural division (Foti 1974) whereas southeastern Arkansas includes part of the Mississippi Alluvial Plain, and the influence of the Ouachita Mountains occurs in the northern part of the region.

Field observations and collections were made by the authors and students at Henderson State University and Southern Arkansas University. Fishes were obtained by the use of seines, amphibians and reptiles were taken by hand, and mammal records were obtained by use of museum special traps or observations of road hit animals.

Specimens of fishes, amphibians, and reptiles were fixed in 10% formalin, stored in 40-50% isopropanol, and are housed at Southern Arkansas University (SAU) and Henderson State University (HSU). Small mammals collected by traps were prepared as museum specimens or, in the case of roadkill, were vouchered via digital photography. Birds also were recorded with digital photography. Due to several recent changes in nomenclature, scientific names of reptiles and amphibians follow “Standard Common and Current Scientific Names for North American Amphibians, Turtles, Reptiles, and Crocodilians, 2009” (http://www.cnah.org/nameIntro.asp).

Class Osteichthyes:

Ichthyomyzon castaneus Girard – Chestnut Lamprey. Robison and Buchanan (1988) initially provided lamprey records for Arkansas. Robison et al. (2006) reported additional lamprey records for Arkansas including some from southern Arkansas. The 2 records presented here provide additional documentation of this rarely taken parasitic species. One specimen was taken from a Moxostoma sucker collected at the Saline River near AR St. Hwy. 172 (Sec. 11, T14S, R9W), Drew County, AR, on 12 June 1989, by H. W. Robison and SAU students. A second specimen was taken from Moro Creek at AR St. Hwy. 160 (Sec. 10, T15S, R12W), Bradley County, AR, on 14 April 1991, by HWR.

Ichthyomyzon gagei Hubbs and Trautman – Southern Brook Lamprey. One specimen of I. gagei was collected from Moro Creek at AR St. Hwy. 275 (Sec. 34, T12S, R12W), Bradley County, AR, on 18 February 1990, by HWR.

Anguilla rostrata (Lesueur) – American Eel. Being catadromous, freshwater eels mature in freshwater then swim downstream to breed in the Sargasso Sea, south of Bermuda. The young return to rivers of eastern North America and migrate upstream, where they mature after several years. However, dams on major rivers have severely limited the extent of the upstream migration, and thus the distribution of American eels (Robison and Buchanan 1988).

Drawdown of water in the lower lake and Caddo River (DeGray Lake system, Clark County) to allow maintenance work on the dam resulted in many fishes becoming entrapped in a concrete rectangle below the spillway. From this area, we captured 35 eels on 3, 5, and 6 March 2010. Most records of eels from Arkansas have been based on specimens caught by fishermen, thus they represent the size classes ranging from 381-762 mm in length (Robison and Buchanan 1988). Smaller eels (less than 400 mm in length) feed largely on aquatic insects (Ogden 1970) so are less often caught on hook-and-line. Most of our 35 individuals, caught with a large aquarium dip net, were less than 400 mm in length and the smallest was only...
205 mm in total length. Variation in sizes observable within the sample of specimens likely represent multiple migrations from the sea, all of whose upstream progress was halted by the dam. The concrete basin did not contain any specimens from the upper end of the size range.

_Esox niger_ Lesueur – Chain Pickerel. In Arkansas, this larger pickerel occurs mostly in the Coastal Plain lowlands and deltaic provinces of the southern and eastern regions of the state (Robison and Buchanan 1988). Spawning is known to occur as early as late February (Keith 1972). On 3 March 2010, we collected 4 specimens of _E. niger_ from the Caddo River below the lower dam of DeGray Lake, Clark County. The specimens were about 25 mm long, suggesting a spawning date of early February – apparently the earliest record of spawning in Arkansas.

_Hybognathus hayi_ Jordan – Cypress Minnow. Robison and Buchanan (1988) reported this species from Coastal Plain areas of Arkansas. The following represent additional records of this species and clarifies its southern distribution in the state. Five specimens were taken in Smackover Creek at AR St. Hwy. 7 (Sec. 32, T15S, R16W), Union County, AR, on 10 July 1991, by HWR. Also in Union County, 2 specimens were collected from Three Creeks at AR St. Hwy. 15 (Sec. 20, T19S, R17W), on 15 September 1988, by HWR.

_Notropis chalybaeus_ (Cope) – Ironcolor Shiner. Robison (1977) discussed the distribution, habitat, and status of _N. chalybaeus_ in Arkansas, and Robison and Buchanan (1988) mapped its occurrence in the state. The following provides additional records of distribution for this uncommon species from south Arkansas. On 6 October 1989, 2 specimens were collected from Three Creeks at AR St. Hwy. 15 (Sec. 20, T19S, R17W), Union County, AR, by HWR and the SAU Vertebrate Natural History class. An earlier collection from Lafayette County at Bayou Bodcau at U.S. Hwy. 82 (Sec. 7, T16S, R23W), on 23 September 1978 by HWR yielded 3 juvenile specimens.

_Moxostoma poecilurum_ (Jordan) – Blacktail Redhorse. Robison and Buchanan (1988) reported this uncommon sucker mostly from the Ouachita River system below its impoundments in south-central Arkansas. A young-of-the-year specimen was collected from farther south, in eastern Union County, from LaPere Creek at AR St. Hwy. 129, 3.2 km (2 mi.) South of Huttig, AR (Sec. 35, T19S, R11W), on 17 October 1992, by HWR and students.

**Class Amphibia:**

_Pseudacris fouquetii_ Lemmon, Lemmon, Collins, and Cannatella – Cajun Chorus Frog (formerly known as Upland Chorus Frog, _P. triseriata_). Although this species is collected commonly and many records exist across the state, Trauth et al. (2004) show only 1 record of this species from Union County, AR. Additional records of _P. fouquetii_ presented herein fill an apparent void in this large county. Two specimens were collected from a roadside ditch ca. 3.2 km (2 mi.) south of Strong on AR St. Hwy. 271 (Sec. 16, R12W, T19S) on 21 February 1989, by HWR. Another individual was taken on 1 March 1992 from a flooded ditch 7 miles south of El Dorado on AR St. Hwy. 7 (Sec. 12, R15W, T19S), by HWR.

_Ambystoma opacum_ (Gravenhorst) – Marbled Salamander. Trauth et al. (2004) showed no records for this amphibian for Hot Spring County, but Robison and McAllister (2006) reported a specimen from the extreme SE corner of the county. We have specimens collected more broadly across the county: near Glen Rose near Ten-Mile Creek (Sec. 3, T4S, R19W), 28 March 2004, HSU 1352; and 17.7 km (11 mi.) SE Bismarck off AR St. Hwy. 283 (Sec. 34, T5S, R19W), 1 March 2000, HSU 621 (2 specimens).

**Class Chelonia:**

Compared with distributions shown in Trauth et al. (2004), we have new county records of 2 turtle species.

_Sternotherus odoratus_ (Latreille) – Stinkpot turtle. A specimen was collected in Clark County, from a pond at the jct. of AR St. Hwys. 51 and 7 (Sec. 16, T7S, R19W), 1 March 2006, HSU 1399.

_Sternotherus carinatus_ (Gray) – Razorback Musk Turtle. Hot Spring County, off Hwy. 67 at Midway, Sec. 5, T6S, R18W, 21 April 2000, HSU 654; 0.4 km (0.25 mi.) W Ouachita River, Grigsby Ford Road, (SE ¼, Sec. 25, T4S, R18W), 27 February 2000, HSU 1040.

This species has not been well-studied in Arkansas, but it is common in DeGray Lake. Over a period of 2 years, we caught, marked, and released 28 individuals within 1 cove near DeGray Lodge in Hot Spring County. These individuals ranged from young with a minimum carapace length of 36 mm (hatchlings are...
23-31 mm – Trauth et al. 2004) to adults with a maximum carapace length of 141 mm (149 mm is the maximum for this species – Trauth et al. 2004). Young specimens (carapace length 36-45 mm, n=12) were caught on 4 dates spanning the month of September (2002, 2003). Further, a 40 mm individual was caught 6 August 2004, and 3 individuals with carapace lengths of 40, 42, and 42 were captured 20 May 2003. Because sampling trips were not taken during all summer months, it is not known whether the reproductive season is bimodal or continuous.

Class Reptilia:

The following localities for collection of lizards and snakes all represent new county records of distribution (Trauth et al. 2004). Unless otherwise noted, the county records fill gaps in which surrounding counties already have published records.

Plestiodon anthracinus pluvialis (Baird) – Southern coal skink (formerly genus Eumeces). Grant County, 14.5 km (9 mi.) N Sheridan off U.S. Hwy. 167 (NE ¼, Sec. 25, T3S, R13W), 23 April 2000, HSU 661.

Plestiodon laticeps Schneider – Broadhead skink (formerly genus Eumeces). Hempstead County, on AR St. Hwy. 73 (Sec. 34, T11S, R26W), 27 January 1998, HSU 262.

Cemophora coccinea copei Jan – Northern Scarlet snake. Pike County, on AR St. Hwy. 84 (Sec. 2, T6S, R25W), 30 May 1998, HSU 410. This locality represents the most westward record for southern Arkansas.

Lampropeltis getula holbrooki Stejneger – Speckled Kingsnake. On 23 May 1990 a single individual of this species was found dead on the road 4.8 km (3 mi.) E of Prattsville on U.S. Hwy. 270 (Sec. 1, T5S, R14W) in Grant County, AR. Because the specimen was mashed severely, no voucher specimen was taken.

Nerodia fasciata confluens (Blanchard) – Broadbanded water snake. Clark County, 0.8 km (0.5 mi.) down Cedar Grove Road off Old Military Road (Sec. 16, T6S, R20W), 30 April 2000, HSU 703; Ouachita Baptist University Pond (Sec. 17, T7S, R19W), 27 March 1998, HSU 226. Hempstead County, 16 km (10 mi.) S Hope, County Road 7 (Springhill) (Sec. 19, T14S, R24W), 4 May 2006, HSU 1457.

Regina rigida sinicola (Huheey) – Gulf crayfish snake. Garland County, Lake Hamilton Primary School (Sec. 26, T3S, R21W), 28 April 2004, HSU 1351. Record extends known distribution NW of records in adjacent Hot Spring and Saline Counties.


Thamnophis sirtalis sirtalis (Linnaeus) – Eastern garter snake. Clark County, 4.8 km (3 mi.) W of Arkadelphia, Mt. Zion Road (Sec. 22, T7S, R20W), 1 October 1996, HSU 835; Skyline Drive, 5.8 km (3.6 mi.) W AR St. Hwy. 7 (Sec. 17, T6S, R20W), 26 March 2000, HSU 702.

Virginia striatula (Linnaeus) – Rough earth snake. Hot Spring County, Malvern (Sec. 25, T4S, R17W), 7 May 2000, HSU 766.

Opheodrys aestivus (Linnaeus) – Rough green snake. Grant County, 14.5 km (9 mi.) N Sheridan off U.S. Hwy. 167 (NE ¼, Sec. 25, T3S, R13W), 25 April 2000, HSU 662.

Class Aves:

Petrochelidon pyrrhonota (Vieillot) – Cliff Swallow. In southern Arkansas, Cliff Swallows historically were considered to be migratory birds, first seen about March and April, as they migrated north to breeding grounds. However, the construction of concrete bridges in southern Arkansas has provided acceptable nest-building localities, permitting the birds to breed throughout most of the southern counties of Arkansas (Tumlison 2007). Within the Gulf Coastal Plain physiographic province, most observations of nests occurred in southwestern counties along the Red River and its tributaries, and only occasional nests were found in eastern counties (with the exception of the lower Ouachita River at the U.S. Hwy. 82 bridge).

On 25 October 2008, 8 new nests of Cliff Swallows were found in Bradley County on the U.S. Hwy. 278 bridge over the Saline River (Sec. 2/3, T13S, R9W). On 26 December 2006, the site contained no nests of the swallows, and the first nests were found.
after the next breeding season, on 5 June 2007 (Tumlison 2009). The 2007 nests were constructed over the river, but the new 2008 nests were located over ground. These observations document the beginning and continued use of the site for breeding.

On 29 December 2007, 3 cliff swallow nests were discovered on the AR St. Hwy. 144 bridge over Connerly Bayou, at its confluence with Lake Chicot, Chicot County, Arkansas (Sec. 25, T15S, R2W). This new record is the easternmost in Arkansas, extending records of breeding almost to the Mississippi River. However, recent observations made 13 February 2010 indicated no new nests, and that the old nests were deteriorating, thus expansion of the breeding range into Chicot County has occurred, but a breeding population does not appear to be established. This nesting record also is only the second record of breeding in the Mississippi Alluvial Plain physiographic province of Arkansas (the other was a single nest over Bayou Bartholomew in Lincoln County (Tumlison 2007)). Of note, Bayou Bartholomew flows southward through eastern Ashley County (and near Chicot County), but no nests have been observed on the U.S. Hwy. 82 bridge that crosses the Bayou.

Tumlison (2009) observed early nesting by cliff swallows in Arkansas, under the U.S. Hwy. 82 bridge on the Ouachita River, Ashley County, on 22 March. On 20 March 2010, 6 cliff swallows had returned to that nesting area and nesting behavior was validated based on nest occupancy and the discovery of failed eggs from the previous year. The eggs had been evicted from nests that were being renovated for the present season. Two broken eggs with dried yolks were discovered directly under the nests, and they were clean – easily distinguished from the heavily sedimented substrate left after the recent floodwaters had receded. Cliff swallows commonly select colony sites and may occupy and renovate old nests if there are few ectoparasites present (Brown and Brown 1995).

Ardea herodias Linnaeus – Great Blue Heron. The Great Blue Heron is a permanent resident in all regions of Arkansas, and individuals have been seen standing in nests as early as late February, although the peak of breeding season occurs during April and May (James and Neal 1986). Heronries (group nesting sites) have been observed in 10 counties (county names were not listed – James and Neal, 1986). We discovered a small heronry off U.S. Hwy. 82, 2.1 km (1.3 mi.) S of Strong, Union County, AR in 2009. On 19 March 2010, Great Blue Herons were seen standing or sitting in at least 10 of the 14 nests. The heronry consists of nests constructed primarily in one hardwood tree (one nest was in a nearby dead pine) located about 200 m from the highway, over water, and at the back edge of a swampy area. When RT approached the edge of the highway to photograph the site on 19 March 2010, the birds dispersed from the site but all returned within 3 minutes. At the time, a maximum of 11 Great Blue Herons were seen at the site.

Class Mammalia:

Marmota monax (Linnaeus) – Woodchuck. The distribution of the woodchuck has been expanding, especially in southwestern Arkansas, during the last decade (Tumlison et al. 2001). A recent survey of wildlife personnel, citizen reports, and new specimen records indicated that the southern expansion had continued into Clark, Pike, Montgomery, and Ouachita counties (Tumlison et al. 2007). During that survey, personnel of the Arkansas Game and Fish Commission (AGFC) reported seeing a woodchuck in Sevier County, but no specifics were given.

On 10 October 2007, David Arbour (a resident of DeQueen, AR, employed by the Oklahoma Department of Wildlife Conservation) photographed a road hit specimen of a woodchuck by the Rolling Fork River Bridge on U.S. Hwy. 70, about 5 km (3.1 mi.) W of DeQueen (Sec. 21, T8S, R32W), Sevier County, AR. This observation represents the most southwestward documented record of the woodchuck in Arkansas.

Sealander and Heidt (1990) provided maps of the known distribution of mammals in Arkansas. An examination of specimens of mammals housed in the vertebrate collections at Henderson State University produced the following list of specimen localities which represent new county records.

Blarina carolinensis (Bachman) – Southern short-tailed shrew. Clark County, 8 km (5 mi.) NW Gurdon, 31 June 1992, HSU 521-523; N of Mill Creek (Sec. 11, T7S R19W), 13 November 2006, HSU 645; 4.8 km (3 mi.) W Arkadelphia, Mt. Zion Road, 23 January 1994, HSU 536.

Cryptotis parva (Say) – Least shrew. Clark County, Arkadelphia, OBU campus, 29 November 2001, HSU 535.

Scalopus aquaticus (Bangs) – Eastern mole. Clark County, AR St. Hwy. 26W, Manor Estates (Sec. 23,
New Records and Notes on the Natural History of Selected Vertebrates from Southern Arkansas

Myotis austroriparius (Rhoads) – Southeastern myotis. Nevada County, Willisville Well N333231.8 W931930.8, 3 May 2000, HSU 486.

Perimyotis subflavus (Cuvier) – Tri-colored bat, formerly known as Eastern pipistrelle. Hot Spring County, 0.4 km (0.25 mi.) off AR St. Hwy. 347, mining shaft, April 1992, HSU 51-53.


Oryzomys palustris J. A. Allen – Marsh rice rat. Clark County, 8 km (5 mi.) NW Gurdon, 31 July 1992, HSU 520; ca. 4.8 km (3 mi.) W of Arkadelphia off Central School Road, 21 January 1992, HSU 59; Hot Spring County (SW ¼, NE ¼, NE ¼, Sec. 11, T5S, R18W), 4 February 1992, HSU 1-3.

Peromyscus gossypinus (Rhoads) – Cotton mouse. Clark County, lower dam at DeGray Lake, 4 December 2001, HSU 456.

Microtus pinetorum V. Bailey – Woodland vole. Clark County, 4.8 km (3 mi.) W Arkadelphia off AR St. Hwy. 26, 20 February 1992, HSU 48. Dallas County, 0.4 km (0.25 mi.) from Crooks Creek, AR St. Hwy. 229, 14 November 2004, HSU 505.

Vulpes vulpes (Desmarest) – Red fox. Sealander and Heidt (1990) noted that the red fox was scarce in the southwestern part of Arkansas, and that populations seem to have been declining in the last 20 years. However, sightings are relatively common in the area around Arkadelphia, Clark County, and DeGray Lake.

For example, RT has photographed a red fox in a wooded area 4.8 km (3 mi.) W of Arkadelphia, Clark County, AR, on 19 August 2006 and 19 April 2008. Also, M. Karnes reported seeing a female red fox with two kits almost daily about 1900 hrs in the evening, from 14 June – 2 July 2009. She was usually lying at the edge of a brush line or sitting at attention while the kits played and wrestled at the edge of a clearing. The female was attentive, but never appeared to fear passing traffic. The location was approximately 1.3 km (0.8 mi.) W of the I-30 overpass on Country Club Road, Clark County, AR (SE ¼ , SW¼, Sec. 12, T7S, R20W).

Further, we have recent specimen records of red foxes in southern Arkansas: Hot Spring County, DeGray Lake near DeGray State Park, 26 December 1998, HSU 356; Drew County, 1.6 km (1 mi.) NW of Monticello, U.S. Hwy. 278, HSU 560.

Acknowledgments

Information and assistance were provided by D. Arbour, M. Karnes, B. Serviss, former SAU students Christa Brummett and Lindsey Fowler, and vertebrate biology classes at Henderson State University and Southern Arkansas University.

Literature Cited


Presence of the Asian Tiger Mosquito (*Aedes albopictus*) in Northwest Arkansas

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The Asian tiger mosquito, *Aedes albopictus* (Skuse), was first documented in the United States in 1985 (Sprenger and Wuithiranyagool 1986). In Asia, adult female *A. albopictus* historically utilized the tree hole habitat as the principle site for oviposition and subsequent larval development. Like other tree hole species, it has quickly adapted to artificial containers readily available in the suburban environment. It is believed to have migrated from Asia to North America on board ships containing automobile tires. Following its documented arrival in Houston, Texas, the interstate shipment of tires has resulted in it being well-established in several states in the Eastern U.S., including Arkansas (Moore et al. 1988) (Jamieson et al. 1994) (Jamieson and Olson 1995). According to Pfitzner et al., (1998), *A. albopictus* is locally abundant and can restrict outdoor human activity within cities located in the Ozarks Mountains Physiographic Region, an area that historically lacked any such problem with pestiferous mosquitoes. In addition, its ability to vector several viral diseases of humans, including dengue fever and encephalitis, has infectious disease experts greatly concerned about its colonization of North America (Hawley 1988, Savage et al. 1994).

In the fall of 2008 and 2009, 35 students enrolled in freshman biology courses at NorthWest Arkansas Community College participated in a biting/probing mosquito survey to determine if the Asian tiger mosquito was the principal pest mosquito in Northwest Arkansas. Sampling occurred from August 30 to October 9 in 2008 and August 25 to October 17 of 2009. Sampling mimicked the methodology of Pfitzner et al., (1998), where students sat in a shaded area on their property for 20 minutes and collected any adult female mosquito attempting to take blood using a wide-mouthed vial. Students were instructed to capture the mosquito while it was probing and before it actually started taking a blood meal. All collections were done within the two hour period before dusk with the intent of maximizing the chances of capturing diurnal, crepuscular, and nocturnal species. Any mosquito captured was killed by being placed in a freezer overnight and subsequently identified using the keys of Darsie and Ward (2005). Collection sites were located in twelve different cities all within Benton and Washington counties. Twenty-two of the thirty-five (63%) collection sites were within the city limits of Fayetteville, Bentonville, Springdale, and Rogers.

A total of 110 mosquitoes representing four genera and seven species was collected. *A. albopictus* represented 79.1% (87 of 110) of mosquitoes collected during the study (Table 1). Two mosquitoes belonging to the genus *Culex* were not identifiable to the species level.

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### Table 1. Species Collected

<table>
<thead>
<tr>
<th>Species</th>
<th>Percentage of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Aedes albopictus</em></td>
<td>79.1</td>
</tr>
<tr>
<td><em>Culex pipiens/quinquefasciatus</em></td>
<td>6.4</td>
</tr>
<tr>
<td><em>Aedes vexans</em></td>
<td>4.5</td>
</tr>
<tr>
<td><em>Ochleratatus trivittatus</em></td>
<td>4.5</td>
</tr>
<tr>
<td><em>Psorophora ferox</em></td>
<td>1.8</td>
</tr>
<tr>
<td><em>Psorophora ciliata</em></td>
<td>0.9</td>
</tr>
<tr>
<td><em>Psorophora cyanescens</em></td>
<td>0.9</td>
</tr>
</tbody>
</table>

The second most frequently encountered species (*Culex pipiens/quinquefasciatus*) only represented 6.4% of the total. Though not abundant during the study, the presence of *C. pipiens/quinquefasciatus* is significant due to its importance as a vector of West Nile fever (Kilpatrick et al. 2005). It should be noted that the keys used did not provide characters for distinguishing adult female *C. pipiens* and *C. quinquefasciatus*. Northwest Arkansas is a region where the ranges of the two species are believed to overlap (Darsie and Ward 2005). The results of this study suggest *A. albopictus* is the principle pest mosquito in this region. In many neighborhoods, it was the only mosquito encountered. Due to the presence of the Asian tiger mosquito, there is now a new public health dilemma in the Ozark Mountains of Arkansas.
Literature Cited


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Salomon Itza, University of the Ozarks

The editorial staff also extends our heartfelt appreciation for the expertise, assistance and valuable time provided by our colleagues who acted as reviewers for the Journal. Expert reviewers were recruited from within Arkansas, other States of the U.S.A, Europe and Asia. Only through the diligent efforts of all those involved that gave freely of their time, can we continue to produce a high quality scientific publication.
Title of a Paper Prepared for the Arkansas Academy of Science Journal (14 point, bold, centered)

A.E. Firstauthor¹, B.F. Second¹, C.G. Third², and D.H. Lastauthor¹ (12 point font, normal, centered)

¹Department of Biology, Henderson State University, Arkadelphia, AR 71999
²Arkansas Game and Fish Commission, 915 E. Sevier Street, Benton, AR 72015 (10 point font, italic, centered)

¹Correspondence: Email address of the corresponding author

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