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ARKANSAS ACADEMY OF SCIENCE
ARKANSAS TECH UNIVERSITY
DEPARTMENT OF PHYSICAL SCIENCES
1701 N. BOULDER AVE
RUSSELLVILLE, AR 72801-2222

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The Arkansas Academy
1917
OF SCIENCE

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

PAST PRESIDENTS OF THE ARKANSAS ACADEMY OF SCIENCE

Charles Brookover	1917
Dwight M. Moore	1932-33
Flora Haas	1934
H. H. Hyman	1935
L. B. Ham	1936
W. C. Munn	1937
M. J. McHenry	1938
T. L. Smith	1939
P. G. Horton	1940
L. A. Willis	1941-42
L. B. Roberts	1943-44
Jeff Banks	1945
H. L. Winburn	1946-47
E. A. Provine	1948
G. V. Robinette	1949
John R. Totter	1950
R. H. Austin	1951
E. A. Spessard	1952
Delbert Swartz	1953
Z. V. Harvalik	1954
M. Ruth Armstrong	1955
W. W. Nedrow	1956
Jack W. Sears	1957
J. R. Mundie	1958
C. E. Hoffman	1959
N. D. Buffaloe	1960
H. L. Bogan	1961
Truman McEver	1962
Robert Shideler	1963
Dwight M. Moore	1964
L. F. Bailey	1965
James H. Fribourgh	1966
Howard Moore	1967
John J. Chapman	1968
Arthur Fry	1969
M. L. Lawson	1970
R. T. Kirkwood	1971
George E. Templeton	1972
E. B. Whittlake	1973
Clark McCarty	1974
Edward Dale	1975
Joe Guenter	1976
Jewel Moore	1977
Joe Nix	1978
P. Max Johnson	1979
E. Leon Richards	1980
Henry W. Robison	1981
John K. Beadles	1982
Robbin C. Anderson	1983
Paul Sharrah	1984
William L. Evans	1985
Gary Heidt	1986
Edmond Bacon	1987
Gary Tucker	1988
David Chittenden	1989
Richard K. Speairs, Jr.	1990
Robert Watson	1991
Michael W. Rapp	1992
Arthur A. Johnson	1993
George Harp	1994
James Peck	1995
Peggy R. Dorris	1996
Richard Kluender	1997
James Daly	1998
Rose McConnell	1999
Mostafa Hemmati	2000
Mark Draganjac	2001
John Rickett	2002
Walter E. Godwin	2003
Wayne L.Gray	2004
Betty Crump	2005
Stanley Trauth	2006
David Saugey	2007
Collis Geren	2008
Joyce Hardin	2009
Scott Kirkconnell	2010
Jeff Robertson	2011
Anthony K. Grafton	2012
Marc Seigar	2013
Jeff Robertson	2014
Abdel Bachri	2015
Ann Willyard	2016

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 FORT SMITH
UNIVERSITY OF ARKANSAS AT FAYETTEVILLE
UNIVERSITY OF ARKANSAS AT MONTICELLO
UNIVERSITY OF ARKANSAS AT PINE BLUFF
UNIVERSITY OF THE OZARKS, Clarksville
UNIVERSITY OF ARKANSAS FOR MEDICAL SCIENCES, Little Rock

EDITORIAL STAFF

ARKANSAS ACADEMY OF SCIENCE 2016

APRIL 1-2, 2016
100th ANNUAL MEETING

University of Arkansas at Fayetteville
Arkansas

JOURNAL
ARKANSAS ACADEMY OF SCIENCE
100th Annual Meeting April 1-2, 2016
University of Arkansas at Fayetteville

In Celebration of the 100th Year of the Arkansas Academy of Science
A Brief History from the Academy's Home Page

Collated by Dr. Collis Geren
AAS Historian

The Arkansas Academy of Science began meeting in 1917 as a group of scientists wishing to establish regular avenues of communication with one another and promote science and the dissemination of scientific information in the state. Over the years since, the Academy has been led by scientists of notable accomplishment, such as Dwight Moore, Ruth Armstrong, C. E. Hoffman, Jewel Moore, Joe Nix, Ed Dale, to name a few. The Academy is a non-partisan, non-political, professional organization consisting of scientists who pay dues to join with other scientists to promote science in the state and region. The specific areas of science included (but not limited to) are Biomedical, Botany, Plant Science, Chemistry, Physics, Astronomy, Engineering, Geology, Environmental Science, Ecology, Invertebrate Zoology, and Vertebrate Zoology.

An Executive Committee, consisting of a President, Past-President, President-Elect, Vice President, Secretary, Treasurer, Journal Editors and Newsletter Editor convenes twice annually to discuss issues and determine some policy and procedures for maintaining and operating the Academy. The chairpersons of standing committees and the President of the Arkansas Science Teachers Association are invited to meet with the Executive Committee.

The Academy holds an annual meeting the second weekend in April during which business is transacted and reports/papers on research and teaching methods are given. The meeting provides many opportunities for colleagues to visit and share information about their respective work. Undergraduate and graduate students also participate and present their work at the Annual Meeting, and the Academy recognizes superior achievement by students with an active awards program.

The major publication of the Academy is the Journal of the Arkansas Academy of Science. The Journal for the previous year is released at the Annual Meeting. Through an exchange program, abstracting services and special subscriptions, the Journal is distributed to approximately 30 of our 50 states and 25 foreign countries.

The Academy also publishes an annual Newsletter, which contains general information about Executive Committee deliberations, the dates of the next annual meeting, programs, and research activities. **Since created, the Academy has had 80 presidents and has published 69 volumes of its Journal, and this issue of the Journal will be the 70th in the Academy's history**

The following is from the 1941 volume of the Journal, which can be readily accessed from the archive maintained on-line at the University of Arkansas Library.

EARLY HISTORY[1]

The Arkansas Academy of Science

L. B. Ham

The Arkansas Academy of Science was organized at a meeting held at the Hotel Marion, January 11, 1917, in accordance with a call issued by Mr. Troy W. Lewis, an aggressive attorney[2] in Little Rock. The following people were present: Charles Brookover, histologist and embryologist; Arthur R. Stover, analytical chemist; D. A. Rhinehart, anatomist; A. C. Shipp, pathologist and bacteriologist; Dewell Gann, Jr., surgical technician; Charles Oates, pharmacologist; and Morgan Smith, pediatrician—each being a member of the staff of the University of Arkansas School of Medicine; Herbert A. Heagney, psychologist and W. H. Aretz, philosopher, — President and Dean of the Little Rock College, respectively; Troy W. Lewis, philologist and sociologist; and William F. Manglesdorf, analytical chemist in private practice at Little Rock.

Dr. Charles Brookover was called to the chair as temporary chairman. The first officers elected were as follows: President, Charles Brookover, Ph. D.; Vice President, Morgan Smith, M.D.; Secretary, Dewell Gann, Jr., M.D.; Treasurer, Herbert A. Heagney, A.M., President Little Rock College; Permanent Secretary (5 years), Troy W. Lewis, A.M., D.C.L. The above were elected also as trustees as well as the following: William F. Manglesdorf, M.D.; Arthur R. Stover, A.M., M.D.; A.C. Shipp, A.M., M.D.; D. A. Rhinehart, M.A., M.D.; Charles E. Oates, M.A., M.D.; and W. H. Aretz, S.T.D. The terms of these trustees were to expire, for the most part, two per year beginning in1918.

The Arkansas general assembly (41st) was then in session. Mr. Lewis read a tentative bill for an Act to Create and Incorporate the Arkansas Academy of Sciences and, on motion, the tentative Act was adopted as the constitution of the body then assembled. The above proposed bill was rejected by the general assembly on its constitutionality, holding that Sec. of Art of the Constitution of 1874 would render such an act void if passed unless the Academy were willing that the state should exercise dominant control. Mr. Lewis took the point of view that the Academy should be free from any political connections and had rejected the state's right to exercise control. He, therefore, withdrew the bill and Incorporated the Academy by an act of the Pulaski Circuit Court. The Academy was incorporated under the name "Arkansas Academy of Sciences". The Academy accepted Mr. Lewis' report at an adjourned meeting, January 22, 1917.

The Academy membership was made up as follows: patrons, members, corresponding members, honorary fellows and fellows. All the above mentioned members were voted in at the organization meeting as fellows, officers and trustees of the Arkansas Academy of Sciences. The Academy had, also a committee each, on the following: rules, auditing, finance, membership, research, and publications and lectures.

The Senate Chambers at the Old State House and the Administration building of the Little Rock College were to be used for the meeting purposes. These quarters were offered the Academy free. Dr. Heagney offered the use of the Little Rock College Laboratories for research purposes, also; and Dr. Manglesdorf offered the use of his private laboratories for research purposes. Dr. Morgan Smith offered the Academy the use of the University of Arkansas Medical School laboratories and buildings for research and assembly purposes.

Other meetings during the year 1917 were as follows: February 1, (special), March 1 (regular) but adjourned, lacking quorum, May (special), August 30 (special), September 5 (special), October 12 (regular meeting).

The following members were elected to membership August 30: Augustine Stoker, O.S.B., New Subiaco Abbey, Subiaco; T. J. Richardson, D.D.S; John P. Almand, architect, Little Rock; Augustine M. Zell, M.D., Little Rock; Walter George Harkey, Lawyer, Little Rock; Woolford B. Baker, teacher of physical and biological sciences; A.D. McNair, agriculturist, U. S. Dept. of Agriculture, Little Rock; H. H. Kirby, M.D., Little Rock.

Because of absences and other duties brought about by the war, the last regular session of the early academy was held October 12, 1917. The sessions consisted of a business session of Trustees (Hotel Marlon), dinner and then adjournment to the Old State House to attend the Annual Program. The Program was as follows: "The Presidental Address" by Morgan Smith, The Action of Some Important Drugs on the Vagus Center" by Charles E. Oates, "Recent Advancement in Internal Secretions" by E.M. Pemberton, "Report on Seventh Facial Nerve in the Albino mouse", by D.A. Rhinehart, "The Contamination of Water Supply" by W.F. Manglesdorf. The following officers were elected for 1918: Pres., Morgan Smith; Vice Pres., Arthur R. Stover; Sec, W. R. Aretz; Treasurer, W. F. Manglesdorf. The following fellow was elected: E.M. Pemberton, B.Sc, M.D., Professor of pathology, University of Arkansas Medical College. The following members were elected: Rev. Henry C. Fromen, B.Sc, A.M., professor of science, Little Rock College; Frank M. Blaisdell, graduate of West Point, Consulting engineer and architect.

The Academy adopted the idea of having one annual meeting. However, the October 12, 1917 session is the only annual meeting of record since the organization functioned scarcely at all after the year 1917. The other earlier meetings were organization sessions to discuss ways to broaden the work and to increase membership. The record shows that other applications for membership were filed but apparently no formal action on the applications was taken, since the organization ceased to function. Among these applications, the following are found: Horace Russel Allen, LL D., major, (Honorary Fellowship proposed), teacher and maker of surgical instruments; Robert S. Medearls, M.D.; John F. Hammett, D.D.S.; Mrs. Bernice Babcock, editorial writer (novels, drama, poetry). Records show no further correspondence beyond the first month of the year 1918, except for an occasional acknowledgment of literature received.

The early Academy was planned on the same order as similar organizations in many other states. Compared to the present organization, the original constitution, with its many classes of members and method of voting, was more formal and conservative and less democratic. The business of the Academy, including the election of officers, was transacted by the trustees. The fellows of the Academy had the power to change the by-laws, to elect the trustees, and to change the number of trustees, except that the number should not be reduced to less than five. In the early form of the constitution the principal office was to be located in Little Rock. After the reorganization in 1932, the principal office was to be in Fayetteville. Both ideas as to principal office have now been abolished. The objects of the original organization were the encouragement and fostering of scientific investigation within our state.

In the early thirties, Dr. D. M. Moore learned of the existence of a charter for an academy but that no meetings were being held. In 1931, he contacted Mr. Troy Lewis, trustee and secretary, to inquire into the possibility of a revival of the academy. It soon appeared that the original members were too scattered to begin where the last session left off. Therefore, a reorganization proved inevitable. For purposes of reorganization, Dr. Moore invited as many of the University faculty as could be reached to meet October 26, 1932, for discussion of the possibility of reviving the academy. Ways of cooperating with existing officers, for election of new officers and of new trustees were discussed. This faculty group voted unanimously in favor of reviving the academy and worked with Dr. Moore in initiating the reorganization. Dr. Moore was made President of this initiating group and L. B. Ham was made the secretary. The two officers, with three, others[3] appointed by the president met October 28 to set up a complete slate of officers and local trustees to be voted upon by the faculty group at the university. The faculty group met November 2, 1932 and elected theremaining officers.[4] With this authority and support from the local group, Dr. Moore went to Little Rock to complete the reorganization at a meeting in Mr. Lewis' office. Dr. Moore was the only other person in attendance at the meeting of the trustees.[5] This report appeared as the 16th "annual meeting of the Board of Trustees of the Arkansas Academy of Sciences, Little Rock, Arkansas, November 9, 1932". The report states also that "all members of the old trustees present either by person or by proxy, except Stover, Shipp, Oates and Heagney, Aretz and Brookover are dead or missing and unaccounted for". Dr. Moore was elected President by the trustees and the slate elected previously in Fayettevllle was confirmed. The new trustees elected in Mr. Lewis' office were as follows: W. M. Manglesdorf, M. Smith, T. W. Lewis, C. F. Allen, Flora A. Haas, L. B. Ham, D. M. Moore, L. C. Price, H. H. Schwardt, L. M. Turner.

The dues of three dollars per year, with an Initiation fee of five dollars, were reduced to one dollar[6] and no Initiation fee at a meeting of the board of trustees on January 6, 1933. The first annual meeting of the revived Academy was held at Hotel Lafayette, Little Rock, April 14-15, 1933. Two new trustees were elected as follows: L. M. Turner to succeed himself and G. C. Branner to succeed W. F. Manglesdorf . In order to make the system of fellows and trustees work, it became the sentiment of the meeting that as fast as fellows were taken into the Academy from the various colleges that the election of the trustees should be made so as to have each institution of higher learning represented by at least one trustee. Much of the last business meeting of the 1933 Academy sessions was devoted to discussions as to possible changes in the by-laws and classification of members. Many of the new members were coming to the conclusion that operating the business of the Academy through trustees was not in keeping with present trends of a scientific organization which is open to every qualified scientific worker or scientifically interested person. The work in connection with possible revision was headed by Dr.

Flora Haas and was reported at the following year's sessions at Conway.

At the Conway sessions, the members finally agreed that the constitution should be revised under a new corporate title and adopted Dr. Haas' report. The present constitution thus dates back to the Conway sessions. The title was changed to "The Arkansas Academy of Science, Arts and Letters," in the hope of interesting workers in other fields.

At the Arkadelphia session in the spring of 1941 Article I of the constitution was changed so that the title now reads, "The Arkansas Academy of Science". Amendments to the by-laws were made at the Arkadelphia meetings in 1935 and in 1941. There have been no major changes in operation of the Academy since the Conway meeting in 1934. The dues have been increased to $1.50 per year beginning in 1942 to take care of the increased costs due to publication of the Academy proceedings.

Two of the early fellows (and trustees) of the Academy gave much time and very helpful assistance in the reorganization. The one, Mr. Lewis, referred to many times previously, gave important assistance in the mechanics of reorganization. The other, Dr. Morgan Smith[7] of the University of Arkansas College of Medicine gave freely of his time to acquaint the new organization with the Academy's past history and with the hopes of the former members. Dr. Smith's wide educational vision, his enthusiasm, and his broad understanding of scientific needs of the state were a great asset to the Academy. Dr. Smith did not live long after the reorganization. The Academy is fortunate to become one of the inheritors of his visions.

On the History of the Journal of the Arkansas Academy of Science

Ivan H. Still, Managing Editor, JAAS

In 1941, Dr. Dwight Moore stated in his Editorial Note to the first edition of what is now the Journal of the Arkansas Academy of Science that “It is with a feeling of mixed pride and humility that this, the first volume of the Proceedings of the Arkansas Academy of Science, is sent forth into a chaotic world.” The second volume of the Proceedings was published in 1947, “with the return of conditions approaching normalcy”. Three years later, Dr. Moore noted “with evidence of marked growth in membership in the Academy and number of sections at the various meetings, the prospects for regular and more frequent appearance of the Proceedings are greatly enhanced. Full cooperation of the members will help these prospects materialize.” Since 1950, the Proceedings, and then, with the name change in 1997, the Journal of the Arkansas Academy of Science has been published each year in hardcopy, available at the following Annual meeting, and archived electronically at the http://libinfo.uark.edu/aas/. The Proceedings and later the Journal has had 11 Editors-in-Chief since Dr. Moore. Of notable longevity is Dr. Stan Trauth, who acted as Editor of the Journal 1993-2007, until Dr. Mostafa Hemmati took over this role in 2008. The Journal celebrates the 70th year of publishing the notable records of Arkansas Science. The Editorial Board honor the past and present visionaries of the Arkansas Academy of Science and look forward to continuing its role in supporting the primary mission of the Academy to “promote a higher standard of education within Arkansas and encourage and promote a higher quality of life through educational opportunities.”

This 2016 annual meeting of the Academy is its 100th. Our host is the University of Arkansas and the meeting site is Fayetteville.
This is the 14th time that Fayetteville has hosted the Academy.

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[1] Taken directly from the records where obtainable

[2] Later, City Judge in Little Rock.

[3] H. Hale, H. H. Schwardt, L. M. Turner

[4] Vice President, D. Swartz; Treasurer, H. H. Schwardt; Trustee, L. M. Turner; Trustee, L. C. Price.

[5] Proxies were held by Mr. Lewis for D. Gann, W. P. Manglesdorf, D. A Rhinehart, M. Smith

[6] The dues have been increased to $1.50 per year beginning in 1942 to take care of the increased costs due to publication of the Academy proceedings.

[7] Dean of University of Arkansas Medical School, first state health officer, representative of Pulaski county in three legislatures. Died September 13, 1935.

Secretary's Report
MINUTES OF THE 100th MEETING

ARKANSAS ACADEMY OF SCIENCE
SPRING 2016 BUSINESS MEETING MINUTES
April 2, 2016 – 11:00 am
BELL 273, University of Arkansas at Fayetteville

1. The meeting was called to order by President Ann Willyard.

2. Local Arrangements Committee: Paneer Selvam

The conference arrangements came out well. Discussed about the Chief Guest, proceedings and donations from the Provost, Vice Provost and Deans of Engineering, Science, Agriculture, Graduate School and Honors College. Each of the office gave $1000. The number of registrants went over 300 and the number of abstracts went over 240.

3. Secretary's Report: Jeff Robertson, Salomon Itza

Minutes from the Executive Committee Meeting of December 5, 2015 minutes were reviewed and approved. Business Meeting of April 11, 2015 was reviewed and approved.

4. Treasurer's Report: Mostafa Hemmati

An accounting of the AAS for 2016 was presented and discussed by the membership. The report was reviewed by the Auditing Committee (Colis and Lois Geren). The auditing committee applauds the work of Treasurer Mostafa Hemmati. The report was clean, all quantities add up. (see AAS financial statement in appendix.)

5. Historian's Report: Collis Geren

Since the historian's report was distributed electronically to all meeting registrants, no formal report was made. (Please see the preface to this volume for the historic founding and early history of the Academy and the Journal).

6. Journal (JAAS #69) Report:
Editor-In-Chief Mostafa Hemmati

During the spring 2015 semester, 27 manuscripts were submitted for consideration for publication in volume 69 of the Journal of the Arkansas Academy of Science (JAAS). Soon after receiving the manuscripts, all manuscripts were sent to reviewers and two Associate Editors. The reviewers sent all manuscripts and their comments back before the end of July 2015.

Reviewers' comments were sent to the authors between July 15, 2015, and July 30, 2015. That process was completed by July 30, 2015. The authors were asked to respond to the reviewers' comments and return their manuscript back to Managing Editor, Dr. Still, by August 31, 2015. That allowed more than a month of time for the authors to respond to the reviewers' comments. In the same letter, the authors were also asked to mail a check for their page charges. August 31, 2015, was also the deadline for receipt of the payment of the page charges; we had to allow longer time for this volume of the Journal.

Five manuscripts required major revisions; however, the remaining manuscripts needed minor revisions. Therefore, volume 69 of the Journal will include 27 manuscripts. In the process of manuscript submission, no manuscripts were lost.

Two Associate Editors, Dr. Collis Geren and Dr. Frank Hardcastle, helped considerably with locating possible reviewers for the manuscripts or serving as reviewer for more than one manuscript. I am grateful for both Associate Editors' assistance. All activities relating to the handling of the manuscripts were performed electronically, and on the whole this expedited the review process. Managing editor post was performed by Dr. Ivan Still and as usual he did an excellent job. The Journal was completed by December 30, 2015. Printing of the Journal was completed by March 2, 2016. I have used Russellville Printing Company for printing of the Journal in the past and I used the same Company this year again.

Managing Editor Ivan Still

There were 27 manuscripts submitted for consideration of publication in volume 69 (2015) of the JAAS.

By the beginning of May these manuscripts were checked for style, grammar, format, etc, to ensure compliance with the "Instructions to Authors". Abstracts were sent to potential reviewers mid to late May. Dr. Hemmati handled Physical Science papers and recruited Drs. Collis Geren, and Dr. Frank Hardcastle to serve as Associate Editors, while Biological Science manuscripts were handled by Dr. Still. All manuscripts were sent out electronically for review by the beginning of June.

These were returned to the Managing Editor at the end of June/middle of July.

Most authors were contacted by e-mail by the middle of July 2015 and informed if their paper was accepted with the need for minor or major revision or whether their paper was rejected. Most manuscripts required minor revision while 5 required major revisions. All authors were asked to return their revisions to the Managing Editor electronically by August 31, with the page charges being submitted to Dr. Hemmati, Editor-in-Chief.

The total number of manuscripts that will published this year is 27 (down from 31 in the previous year), of which 17 were Articles, 10 were in General Note format. The Journal was completed at the end of December when the Membership list and the final Treasurer's report was added. The Volume 69 was 170 pages long (including cover pages) and was sent for printing in January 2016.

I would like to thank the reviewers and Assistant/Associate Editors for their help in the preparation of volume 69, and finally the corresponding authors of submitted manuscripts and the reviewers for the their efforts in maintaining the quality of the journal.

Revision of Journal policies to maintain membership of the Directory of Open Access Journals:

Beth Juhl contacted me at the end of 2015 regarding our continued registration with the Directory of Open Access Journals. With the predatory practice of so-called Open Access Journals, the DOAJ tightened up, and required additional criteria for continued inclusion in the Directory. The following items were addressed as a requirement and where necessary added to the Journal Web site: 1) update to Journal's aims and scope; 2) a set editorial board of five members (already provisioned in the AAS Constitution), with contact information included; 3) the author guidelines; 4) clear Journal policies to maintain quality of the peer review process, academic honesty and integrity, including references to COPE's guidelines (available at http://publicationethics.org/resources/guidelines); and 5) copyright and Open Access statement. Full updates can be viewed at the Journal Website http://www.arkansasacademyofscience.org//aasjournal.html

Matters arising from assessment of abstracting of the Journal.

Previous journal issues have included a statement regarding where the journal is abstracted. This was inherited from when Dr. Hemmati and I took over the management of the Journal. Several of these services have come under Thomson Reuters and will require reapplication, and possible monies, while some may no longer be appropriate (Anthropology, for instance, as no papers on this subject have been submitted for a while), and one no longer exists (1985 last issue!). Thus, I have removed this statement for the interim until I am able to investigate this matter further.

7. Webmaster: Salomon Itza

Salomon reported that he is leaving Arkansas. He will be missed.

8. Newsletter: Panneer Selvam

The newsletter for January was issued and publicized through email. The committee recommended to have a simple publication for the fall.

9. Committee Reports:

Nominations Committee: Mostafa Hemmati

Ed Wilson inherited the presidency of the Academy, with Paneer Selvam as President-elect, Ann Willyard as Past-President, and Frank Hardcastle nominated as Vice President. Dr. Collis Geren was nominated to the position of Secretary, Kim Smith the post of Historian and Rami Alroobi, Webmaster. A new positon in charge of Undergraduate Research Grants will be filled by Jess Kelly.

10. Business Old and New:

Professor Stephen Addison proposed the University of Central Arkansas as the site of the 2017 meeting (101st)

Arkansas State University has volunteered to host the 102nd meeting in 2018.

AAS Undergraduate Research Awards ($500) were given to support undergraduate research. Recipients of the 2016 awards were Amanda Brooks, Anna Sharabura and James Allen Jackson.

Student Awards were presented at the 100th AAS meeting and are detailed in Appendix A.

11. Motions and Action Items:

Approval of the 2016-17 AAS budget for up to $7,000 yearly, outside of journal publication costs, which includes student presentation awards, student research awards, and funding for affiliate organizations was sought. Moved by Hemmati and Seconded by Still. It was approved.

Ed Wilson was installed as President, with Paneer Selvam President-Elect, Frank Hardcastle as Vice President and Ann Willyard becomes Past President. All other nominations were accepted.

Meeting was adjourned at 12:03 P.M.

Draft submitted by Salomon Itza, to Dr. Geren, acting AAS Secretary, May 18 2016

Treasurer's Report
ARKANSAS ACADEMY OF SCIENCE
2016 FINANCIAL STATEMENT
December 13, 2016

Balance – November 4, 2016	**$127,944.53**
Balance – December 1, 2015	**$110,045.33**
Net Gain	**$17,899.20**

DISTRIBUTION OF FUNDS

Checking Account - Arvest Bank, Russellville	$24,888.34
PayPal Account available Funds on December 13, 2016	$697.75
Certificate of Deposit Includes Phoebe and George Harp Endowment Arvest Bank, Russellville	$51,179.22
Certificate of Depoit Arvest Bank, Russellville	$51,179.22

Combined interest from Arvest Bank alone since December 01-December 13, 2016: $134.72+ $134.72 = $269.44

TOTAL	**$127,944.53**

INCOME:

1. Transfer from CD to Checking		**$50,000.00**
2. GIFTS RECEIVED		
a. Ouachita National Forest - Sponsorship		$0
b. Contribution, Collis Geren		$250
c. Contribution, Geren ($250) +Returned Check $25		$275
		$525
3. INTEREST (Interest Earned Year to Date)		
a. Checking Account, Arvest Bank	1290	$0
b. CD1 (Arvest Bank)	1357	$134.72
c. CD2 (Arvest Bank)	1358	$134.72
All interest was added to the CDs		**$269.44**
4. JOURNAL		
a. Page Charges		$13,300
b. One Copy of Vol. 69		$50
c. Suscriptions, University of Arkansas		$900
d. One Copy of Vol. 69		$50
e. One Copy of Vol. 70, IBSCO		$50
		$14,350
5. MISCELLANEOUS INCOME		**$0**
6. MEMBERSHIP		
a. Associate		$15
b. Individuals		$370
c. Membership Fees from Meeting		$930
d. Other Dues- From Meeting		$35
c. Institutional (UAMS, $100) + UAF$100+Lyon$100)		$300
d. Life (Bullock, Secd-$125; Kelly, Secd. $125; Selvam, $500; Liner $500); Collis had recorded $625 as Well		$1,250
e. Sponsoring		$45
f. Sustaining		$35
		$2,980
7. MEETING INCOME		
a. Student Registration and Fees		$3,480
b. Faculty Registration and Fees		$3,000
b. Additional Meeting Income-Last Check		$1,683.66
		$8,163.66
TOTAL INCOME		**$26,018.66**

EXPENSES

1. STUDENT AWARDS	**$4,025**
2. AWARDS (Organizations)	
a. Junior Science and Humanities Sym.	$400
b. Arkansas State Science Fair	$400
c. Arkansas Junior Academy of Science	$250
d. Arkansas Science Talent Search	$150
	$1,200

3. UNDERGRADUATE RESEARCH AWARDS

a. Dr. MacDonald, Hendrix	$500
b. Ms. Dalton, ATU	$500
c. Dr. Kelly, Ouachita	$500
	$1,500

4. JOURNAL

a. Volume 69 Printing Cost	$2,622.87
	$2,622.87

5. MISCELLANOUS EXPENSES

1. Extra Registration Fee Refund, Dr. Willyard	$40
2. Extra Registration Refund- Nasaya	$40
3. EXCOM Lunch, Hemmati	$54.17
4. Journal Mailing Cost	$68.46
5. Student Presentation Award's Mailing Cost	$3.77
6. Membership Fee Refund	$30
7. Website Registration	$36
8. Life Membership Refund	$500
	$772.40

6. TRANSFER TO CD from Checking	**$50,000**
7. MEETING EXPENSES	**$0.00**
TOTAL EXPENSES	**$10,120.27**

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COST OF JOURNAL

VOLUME	COPIES	PAGES	PRINTER CHARGE	TOT. VOL. COST	COST/ COPY	COST/ PAGE
36 (1982)	450	110	$5,233.28	$5,291.69	$11.76	$48.11
37 (1983)	450	103	$5,326.91	$5,944.44	$13.21	$57.71
38 (1984)	450	97	$5,562.97	$6,167.72	$13.71	$63.58
39 (1985)	450	150	$7,856.20	$8,463.51	$18.81	$56.42
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41 (1987)	450	116	$7,122.79	$7,811.25	$17.36	$67.34
42 (1988)	450*	116	$7,210.79	$7,710.15	$17.13	$66.47
43 (1989)	450*	119	$8,057.24	$8,557.24	$19.02	$71.91
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48 (1994)	450	270	$17,562.46	$18,262.46	$40.58	$67.63
49 (1995)	390	199	$14,725.40	$15,425.40	$39.55	$77.51
50 (1996)	345	158	$11,950.00	$12,640.75	$36.64	$80.00
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53 (1999)	350	160	$13,686.39	$14,386.39	$41.10	$89.91
54 (2000)	350	160	$14,149.07	$14,849.07	$42.43	$92.81
55 (2001)	360	195	$16,677.22	$17,498.22	$48.61	$89.73
56 (2002)	350	257	$18,201.93	$19,001.93	$54.29	$73.94
57 (2003)	230	229	$14,415.12	$15,715.12	$68.33	$68.62
58 (2004)	210	144	$7,875.76	$9,175.76	$43.99	$63.72
59 (2005)	215	226	$16,239.04	$17,835.84	$82.96	$78.92
60 (2006)	220	204	$11,348.06	$12,934.30	$58.79	$63.40
61 (2007)	195	150	$8,196.84	$9,914.69	$50.84	$66.10
62 (2008)	220	166	$2,865.00	$2,967.49	$13.49	$17.88
63 (2009)	213	206	$3,144.08	$3,144.08	$14.76	$15.26
64 (2010)	232	158	$2,713.54	$2,764.30	$11.91	$17.50
65 (2011)	200	194	$2915.12	$2,963.03	$14.82	$15.27
66 (2012)	200	216	$3,087.91	$3,180.29	$15.90	$14.72
67 (2013)	200	238	$3,311.42	$3,396.32	$16.98	$14.27
68 (2014)	180	192	$2,812.75	$2,944.08	$16.36	$15.33
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- 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.
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- 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

AWARD WINNERS FROM THE 100TH ANNIVERSARY AKANSAS ACADEMY OF SCIENCE (awardees are underlined)

UNDERGRADUATE ORAL PRESENTATION AWARDS: Chemistry

1st Place

Cholesterol Influence on Arginine-Containing Transmembrane Peptides by Jordana K. Thibado; Ashley Martfeld; Denise Greathouse; Roger Koeppe. University of Arkansas, Fayetteville

2nd Place

Small Molecule Inhibitors of System xC by John Kreun; Allen Snider; Mariusz P. Gajewski. Arkansas Tech University

3rd Place

Length – Valence Relationship for Carbon – Nitrogen Chemical Bonds by Connor Harris; Franklin D. Hardcastle. Arkansas Tech University

GRADUATE ORAL PRESENTATION AWARDS: Chemistry

1st Place

Varied Approaches to the Ionization Behavior of Specific Glu Residues That Face the Lipids in Transmembrane Helices by Venkatesan Rajagopalan; Denise V. Greathouse; Roger E. Koeppe II. University of Arkansas, Fayetteville

2nd Place

Evidence for a New Phase of Liquid Buried in Experimental Surface Tension Measurements of Supercooled Water by Ryan Rogers; Kai-Yang Leong; Feng Wang. University of Arkansas Fayetteville

3rd Place

Stereospecific Reduction of R- and S- Warfarin by Human Hepatic Cytosolic Reductase by D. A. Barnette[1]; D. L. Pouncey[2]; R Nshimiyimana[2]; L. P. Desrochers[2]; D.K. Hammon[2]; T. E. Goodwin[2], G. P. Miller[1]. University of Arkansas for Medical Sciences[1]; Hendrix College[2]

UNDERGRADUATE POSTER PRESENTATION AWARDS: Chemistry

1st Place

Determining Diffusion Coefficients in Bulk Solution and Through Membranes Using Electrochemical Time of Diffusion (ETOD) by Madeline Meier; Jon Moldenhauer; David Paul. University of Arkansas, Fayetteville

2nd Place

Helix Fraying May Stabilize Transmembrane Alpha Helices by Armin Mortazavi; Venkatesan Rajagopalan; Roger E. Koeppe II. University of Arkansas, Fayetteville

3rd Place

Determination of Fatty Acid Concentrations in Algae by Donnell White; Beth Justice; Drake Palazzi. University of Arkansas at Monticello

GRADUATE POSTER PRESENTATION AWARDS: Chemistry

1st Place

Engineering the Structure of Fibroblast Growth Factor through Site Directed Mutagenesis for Increased Protein Stability by Julie Davis; Srinivas Jayanthi; T.K.S. Kumar. University of Arkansas, Fayetteville

GRADUATE POSTER PRESENTATION AWARDS: Molecular and Cellular Biology

1st Place

Characterization of the Thioredoxin System in *Methanosarcina acetivorans* Reveals Complexity of the System in Methanogens by Addison C. McCarver; Faith H. Lessner; Daniel J. Lessner. University of Arkansas, Fayetteville

2nd Place

Simplifying Gene Stacking in Plants using Site Specific Recombinases and Nucleases by Bhuvan Pathak; Jamie Underwood, Soumen Nandy; Shan Zhao; Vibha Srivastava. University of Arkansas, Fayetteville

3rd Place

Precision Medicine: A Case for Exemestane Therapy by Bryana J. Gregory; Joshua D. Simpson; Nour M. Hussein Harding University College of Pharmacy

UNDERGRADUATE POSTER PRESENTATION AWARDS: Molecular and Cellular Biology

1st Place

Identification of the Gene Defective in J56, an *Arabidopsis* Auxin-conjugate Response Mutant by Ahmed Stivers[1]; Bethany Zolman[1]; Rebekah Rampey[2] . Harding University[1]; University of Missouri-St. Louis[2]

2nd Place

Identification of Important Residues in *Arabidopsis* IBR3 Using Site-directed Mutagenesis and Mutant Phenotype Complementation assays by <u>Amy Scott</u>[1]; Rebekah Rampey[1]; Bethany Zolman[2]. Harding University[1]; University of Missouri- St. Louis[2]

3rd Place

Fatty Acid Metabolism Controlled by NHR-80 and NHR-49 is Necessary for *Caenorhabditis elegans* to Survive in Severe Hypoxia by <u>Quinton Anderson</u>; Ben Saunders; Jo Goy. Harding University

GRADUATE ORAL PRESENTATION AWARDS: Molecular and Cellular Biology

1st Place

GTP Hydrolysis Is Not Required by Chloroplast Signal Recognition Particle and its Receptor for Post Translational Targeting and Insertion of Integral Thylakoid Membrane Proteins by <u>Priyanka Sharma</u>; Ralph L. Henry; Robyn L. Goforth; Alicia D. Kight. University of Arkansas, Fayetteville

2nd Place

Mitochondrial CYP2E1 Drives Butadiene-induced Mitochondrial Dysfunction by <u>Jessica H. Hartman</u>[1]; Andres A. Caro[2]; Gunnar Boysen[1]; Grover P. Miller[1]. University of Arkansas for Medical Sciences[1]; Hendrix College[2]

3rd Place

Methanogens as Ideal Candidates for Life on Mars: Tolerance to Pressure, Temperature and Clays by <u>Rebecca L. Mickol</u>[1]; Yuta A. Takagi[2]; Tim A. Kral[1]. University of Arkansas[1]; Oberlin College[2]

UNDERGRADUATE ORAL PRESENTATION AWARDS: Molecular and Cellular Biology

1st Place

The Effects of Type of Information and Type of Exposure on Attitudes about Mental Illness by <u>Jessica Bonumwezi</u>; Kelly Brice. Hendrix College

2nd Place

Growth of Methanogens in the Presence of Perchlorate Salts: A Study for Possible Life on Mars by <u>John Cale</u>; Rebecca L. Mickol; Tim A. Kral. University of Arkansas, Fayetteville

3rd Place

Phenotypic Variation of a Segregating Blackberry Population for Molecular Marker Development by <u>Loren M. Anthony</u>; John R. Clark; Daniela Segantini. University of Arkansas, Fayetteville

GRADUATE POSTER PRESENTATION AWARDS: Field Biology and Ecology

1st Place

Population Dynamics of Chelonians in an Urban Lake in Jonesboro, Craighead County, Arkansas by <u>J.D. Konvalina</u>; C.S. Thigpen; S.E. Trauth. Arkansas State University

2nd Place

Vegetation Diversity in Natural and Restored Forested Wetland Sites in Southeast Arkansas by <u>Chris Sheldon</u>; Robert L. Ficklin; Karen Fawley. University of Arkansas at Monticello

UNDERGRADUATE POSTER PRESENTATION AWARDS: Field Biology and Ecology

1st Place

Distribution and Abundance of Introduced Seal Salamanders (*Desmognathus monticola*) in Northwest Arkansas, USA by <u>Clint Bush.</u> University of Arkansas, Fayetteville

2nd Place

An Ecological Study of the Burrowing and Feeding Habits of *Coronis scolopendra* Latreille (Stomatopoda: Nannosquillidae) by <u>Addison Ochs</u>. Southern Arkansas University

GRADUATE ORAL PRESENTATION AWARDS: Field Biology and Ecology

1st Place

Relative Wildlife Community Metrics within Arkansas State Parks by <u>Bennett Grooms</u>[1]; Rachael Urbanek[2]. Arkansas Tech University[1]; University of North Carolina Wilmington[2]

2nd Place

Allelopathic Influence of Eucalyptus on Three Common Kenyan Farming Crops by <u>Brandy Garrett Kluthe</u> University of Arkansas, Fayetteville

UNDERGRADUATE ORAL PRESENTATION AWARDS: Field Biology and Ecology

1st Place

Indirect Effects of Leaf-cutter Ants on the Litter Arthropod Community in a Tropical Rainforest by <u>Rachel Wells</u>[1]; Serena Murphy[2]; Matthew Moran[1]. Hendrix College[1]; University of Georgia, Costa Rica[2]

2nd Place

The Effects of Shade on Greenhouse-grown Primocane Fruiting Blackberries by Olivia Caillouet; Curt Rom; Jason McAfee. University of Arkansas, Fayetteville

3rd Place

Impacts of Shale Gas Development on Breeding Birds in the Eastern United States by Kevin J. Krajcir; Annie Meek; Matthew D. Moran; Maureen R. McClung.
Hendrix College

UNDERGRADUATE ORAL PRESENTATION AWARDS: Botany

1st Place

Phylogeography of Jeffrey Pine in the Klamath Mountains by Julia Lefler; Ann Willyard Hendrix College

2nd Place

Mitochondrial Lineages of *Pinus ponderosa* s.l. in the USA and Related Species in Mexico and Central America by Hassan Hussein Karemera; Ann Willyard. Hendrix College

UNDERGRADUATE ORAL PRESENTATION AWARDS: Physics

1st Place

The Effect of Space Radiation and Microgravity on Chromosome Aberrations in Human Endothelial Cells by Cullen Shaffer[1]; Abdel Bachri[1]; Rupak Pathak[2]. Southern Arkansas University[1]; University of Arkansas for Medical Sciences[2]

2nd Place

Electron Shock Waves with a Large Current behind the Shock Front by Hunter Newberry; Mostafa Hemmati. Arkansas Tech University

GRADUATE ORAL PRESENTATION AWARDS: Physics

1st Place

Two-dimensional Disorder in Black Phosphorus and Monochalcogenide Monolayers at Finite Temperature by Mehrshad Mehboudi[1]; Salvador Barraza-Lopez[1]; Alex M. Dorio[1]; Hugh O. H. Churchill[1]; Alejandro A. Pacheco-Sanjuan[2]; Edmund O. Harriss[1]; Pradeep Kumar[1].
University of Arkansas[1]; Universidad del Norte[2]

2nd Place

Universal Energetic Coupling in Complex Antiferroelectric and Incommensurate Perovskites by Kinnary Patel[1]; Sergey Prosandeev[1,2]; Yurong Yang[1]; Bin Xu[1]; Jorge Ìñiguez[3]; L. Bellaiche[1] . University of Arkansas[1]; Southern Federal University, Russia[2]; Luxembourg Institute of Science and Technology[3]

3rd Place

Double Groups in Molecular Physics by Bradley Klee. University of Arkansas, Fayetteville

UNDERGRADUATE POSTER PRESENTATION AWARDS: Physics

1st Place

Nanoparticle Size and Shape Characterization with Solid State Nanopores by Santoshi Nandivada; Jiali Li; Mourad Benamara. University of Arkansas, Fayetteville.

2nd Place

Detect Binding Sites and Efficiency of Binding of RNAP Holoenzyme on λ DNA Attached to a Probe Tip with Solid State Nanopores by Harpreet Kaur; Santoshi Nandivada; Mitu Chandra Acharjee; Changbae Hyun; Min Xiao; David McNabb; Jiali L. University of Arkansas, Fayetteville

GRADUATE POSTER PRESENTATION AWARDS: Physics

1st Place

Changes in Elasticity of Rat Bones Exposed to Simulated Microgravity and Radiation by Hayley Heacox[1]; Lawrence M. Benzmiller[1]; Rahul Mehta[1]; Max Dobretsov[2]; Parimal Chowdhury[2]. University of Central Arkansas[1]; University of Arkansas for Medical Sciences[2]

2nd Place

SIMION Model of an Electrostatic Positron Storage Ring by Nicole Nichiniello; Jared Gavin. University of Arkansas at Monticello

3rd Place

Measuring Nonlinear Parameters of Graphene Materials Using Z-Scan Technique by Thekrayat Alabdulaal; Gregory Salamo. University of Arkansas, Fayetteville

UNDERGRADUATE ORAL PRESENTATION AWARDS: Computing Science

1st Place

A Support Vector Machine Based Model for Predicting Heparin-binding Proteins using XB patterns as Features by Joseph Sirrianni; Wing Ning Li; Thallapuranam Suresh Kumar. University of Arkansas, Fayetteville

UNDERGRADUATE POSTER PRESENTATION AWARDS: Computing Science

1st Place

Rules for Differentiating Between Non-Isomorphic Graphlets by John Calvin Alumbaugh; Dale R. Thompson. University of Arkansas, Fayetteville

GRADUATE POSTER PRESENTATION AWARDS: Computing Science

1st Place

PrivacyCamera: Cooperative Privacy-Aware Photographing with Mobile Phones by Ang Li[1]; Qinghua Li[1]; Wei Gao[2] . University of Arkansas[1]; University of Tennessee[2]

2nd Place

The Effects of Denial-of-Service Attacks on Secure Time-Critical Communications in the Smart Grid by Fengli Zhang; Qinghua Li; Chase Ross. University of Arkansas, Fayetteville

3rd Place

IPv6 Security Performance Analysis by Adrian Ordorica; Dale R. Thompson. University of Arkansas, Fayetteville

UNDERGRADUATE ORAL PRESENTATION AWARDS: Engineering

1st Place

Electrospun Poly-Ethylene Oxide Nanofibers by Hope Schneider; Daniel Bullock; Jim Steuber. Arkansas Tech University

2nd Place

Android Control of Science Instruments by Daniel Grant; Maria Medrano; Edmond Wilson. Harding University

3rd Place

Persistent and Controllable Weather Balloons as High Altitude Test Vehicle by Maxwell Martin; Adam Huang University of Arkansas Fayetteville

GRADUATE ORAL PRESENTATION AWARDS: Engineering

1st Place

Engineering Biphasic Janus-type Polymer-Protein Nanofibers via Centrifugal Jet Spinning by Prashanth Ravishankar; Alex Khang; Kartik Balachandran University of Arkansas, Fayetteville

2nd Place

Effect of Quinhydrone-Methanol Passivation on Hydrogenated and Standard Boron Emitters by Matthew Young; Hameed Naseem. University of Arkansas, Fayetteville

3rd Place

Environmental Sustainability of Distribution-retail Networks in the United States by Jasmina Burek; Darin Nutter. University of Arkansas, Fayetteville

UNDERGRADUATE POSTER PRESENTATION AWARDS: Engineering

1st Place

Properties of GaN/SiC Heterostructures for Harsh Environment Power Devices by Stephanie Sandoval; Chen Li; Morgan Ware; Zhong Chen . University of Arkansas, Fayetteville

GRADUATE POSTER PRESENTATION AWARDS: Engineering

1st Place

Systematic Study of Si-based Ge/Ge0.9Sn0.1/Ge Photodiodes with 2.6 µm Detector Cutoff by Thach Pham. University of Arkansas, Fayetteville

2nd Place

Optical Properties Study of Ge1-xSnx Alloys by Spectroscopic Ellipsometry by Huong Tran. University of Arkansas, Fayetteville

3rd Place

Temperature Dependent Study of GeSn Light-emitting Diodes on Si for Mid-infrared Applications by Yiyin Zhou. University of Arkansas, Fayetteville

UNDERGRADUATE ORAL PRESENTATION AWARDS: Geoscience

Lower Mississippian Chert Development, Southern Midcontinent Region by Julie M. Cains. University of Arkansas, Fayetteville

GRADUATE ORAL PRESENTATION AWARDS: Geoscience

1st Place

Sourcing Diagenetic and Mineralizing Fluids of Mississippi Valley-Type Ores along the Cincinnati Arch by William Travis Garmon; Adriana Potra; Andrew H. Wulff. University of Arkansas, Fayetteville

2nd Place

Comparison of the Elemental Geochemistry of the Boone Chert and the Arkansas Novaculite by John Philbrick. University of Arkansas, Fayetteville

3rd Place

GS-Carbon Sequestration at Pea Ridge National Military Park in NW Arkansas from a Terrestrial/Biological Perspective by Dorine Reed Bower. University of Arkansas, Fayetteville

GRADUATE POSTER PRESENTATION AWARDS: Geoscience

Floodplain Soils—A Potential Source of Phosphorus to the Illinois River by Megan Lord; Brian Haggard. University of Arkansas, Fayetteville

APPENDIX B
RESOLUTIONS

Arkansas Academy of Science
100th Annual Meeting, 2016 Resolutions

Be it resolved that we, the membership of the Arkansas Academy of Science (AAS) offer our sincere appreciation to University of Arkansas for hosting the 100th annual meeting of the Academy. We thank the local arrangements committee: R. Panneer Selvam (Chair), Collis Geren and Jim Rankin (Co-Chair) and the Provost and Deans who supported the awards and volunteering Faculties listed in the AAS proceedings.

We sincerely thank University of Arkansas for providing its facilities and service during the meeting and Chartwell for the catering service.

We especially thank our keynote speaker, Chancellor Joseph Steinmetz for his inspiring talk.

The Academy recognizes the important role of our session chairs: David Andrews (UAF), Abdel Bachri (SAU), Doug Barron (ATU), Van Brahana, (UAF retired), Daniel Bullock (ATU), James Daly (UAMS retired), Wei Du (UAF), Jess Kelly (Ouachita Baptist), Walt Manger (UAF retired), Travis D. Marsico (ASU), Grover Miller (UAMS), Dennis Provine (Harding), Andy Sustich (ASU), Abraham Tucker (SAU), Francis Umesiri (JBU), and Brian Wagner (AR Game & Fish)

Even greater appreciation and sincere gratitude is extended to our dedicated judges for the student presentations including David Andrews (UAF), Doug Barron (ATU), Van Brahana (UAF retired), Hugh Churchill (UAF), Steve Cooper (Harding), Wei Du (UAF), Jared Gavin (UA Monticello), Collis Geren (UAF retired), Frank Hardcastle (ATU), Mostafa Hemmati (ATU), Salomon Itza (College of the Ozarks), Steve Moore (Harding), James Musser (ATU), Kim Needy (UAF), Antoinette Odendaal (SAU), Dennis Provine (Harding), Amber Sierra (ATU), Kim Smith (UAF), Mary Stewart (SAU), Suresh Thallapuranam (UAF), Abraham Tucker (SAU), Teresa Turk (NOAA retired), Susan Wache (SACC), Jessica Young (ATU) and Andrew Zhou (UAF).

We congratulate our student researchers, scientists and engineers who presented papers and posters, whose efforts contribute directly to the future success of the Academy and the improvement of advancement of science in Arkansas.

The Academy recognizes its leadership and offers its thanks to this year's set of executive officers including Ann Willyard (President), Ed Wilson (President Elect), Abdel Bachri (Past President), Panneer Selvam (Vice President), Mostafa Hemmati (Treasurer and Journal Editor-in-Chief), Ivan Still (Journal Managing Editor), Panneer Selvam (Newsletter Editor), Salomon Itza (Webmaster), Collis Geren (Historian), and Jeff Robertson (Secretary).

Respectfully submitted on this 2nd day of April, 2016. Resolutions Committee: Ann Willyard (President), and Panneer Selvam (Chair of local organizing committee).

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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 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 "Washita" 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. HENRY W. "Rob" ROBISON

Dr. Henry W. Robison, Ph.D. is Emeritus Distinguished Professor of Biology, Southern Arkansas University, Magnolia. "Rob", as he is known amongst his colleagues, is a renowned ichthyologist and natural historian. He served as President of AAS in 1980-1981 and was long-time historian of the society from 1984 to 2007. Rob is coauthor of several books on Arkansas biota, including *Fishes of Arkansas* (Robison and Buchanan 1988), *Only in Arkansas* (Robison and Allen 1995), and *Amphibians and Reptiles of Arkansas* (Trauth et al. 2004). He and Tom Buchanan have produced a second edition of *Fishes of Arkansas* and it is in the process of being published by UA Press. Rob has published over 66 papers in the *Journal of the Arkansas Academy of Science*, his first article was in the then *Proceedings* with his long-time mentor, Dr. George Harp (Robison and Harp 1971). In addition, he has over 350 published papers in the scientific literature.

By the early age of 14, Rob had already decided to become an ichthyologist. He attended Arkansas State University (ASU) and received his B.S. degree in 1967. At ASU he also earned an M.S. in biology in 1968 under the tutelage of Dr. Harp. Rob pursued a Ph.D. at Oklahoma State University in zoology under the direction of Dr. Rudolph Miller where he obtained the degree in 1971. During that period he also coauthored a book with Miller entitled, "*Fishes of Oklahoma*" (Miller and Robison 1973). A second edition of *Fishes of Oklahoma* was also published with Dr. Miller (Miller and Robison 2004).

Rob immediately found employment following graduation and his first faculty position was a summer teaching position at Southern Illinois University in Carbondale. In August 1971, he accepted a tenure-track teaching position at SAU where he taught the next 37 yr before retiring in 2008. Rob received the Excellence Award for Research at SAU in 1993 and 2008, becoming the only person to receive it twice. He also received the W. Frank Blair Eminent Naturalist Award in 2012 from the Southwestern Association of Naturalists.

Rob has not slowed down since retirement and tries to get into the field as much as possible. His hobby is photography and he continues research on crayfishes and the endemic biota of Arkansas. Rob has the distinction of having several species named in his honor, including *Bouchardina robisoni*, *Eimeria robisoni*, *Homalometron robisoni*, *Kongsbergia robisoni* and *Ochrotrichia robisoni*.

Dr. Robison is married and has two children and seven grandchildren. A recent article on his life appeared in American Currents (Robison 2015).

C.T. McAllister
Science and Mathematics Division,
Eastern Oklahoma State College, Idabel, OK 74745

Literature Cited

Miller RJ and **HW Robison**. 1973. The fishes of Oklahoma. Oklahoma State University Museum of Natural History and Cultural History (Stillwater). Series No. 1. 246 p.

Miller RJ and **HW Robison**. 2004. The fishes of Oklahoma. 2nd edition. University of Oklahoma Press (Norman). 450 p.

Robison HW. 2015. Where I got to where I am today. American Currents 40:36-38.

Robison HW and **TM Buchanan**. 1995. Only in Arkansas: A study of the endemic plants and animals of the state. University of Arkansas Press (Fayetteville). 121 p.

Robison HW and **TM Buchanan**. 1988. Fishes of Arkansas. University of Arkansas Press (Fayetteville). 536 p.

Robison HW and **GL Harp**. 1971. A pre-impoundment limnological study of the Strawberry River in northeastern Arkansas. Proceedings of the Arkansas Academy of Science 25:70-79.

Trauth SE, **HW Robison** and **MV Plummer**. 2004. The amphibians and reptiles of Arkansas. University of Arkansas Press (Fayetteville). 421 p.

KEYNOTE ADDRESS

Chancellor Joseph Steinmetz

University of Arkansas at Fayetteville

Biography: Joseph E. Steinmetz became the sixth chancellor of the University of Arkansas on January 1, 2016. Prior to this appointment, he was Ohio State's chief academic officer. As executive vice president and provost, he oversaw the administration, coordination, and development of all academic functions of the university.

Dr. Steinmetz came to Ohio State in 2009 to serve as vice provost for arts and sciences and executive dean of the then-new College of Arts and Sciences. With his leadership, the former five independent colleges of arts and sciences were unified into the largest arts and sciences college in the country. Before coming to Ohio State, Dr. Steinmetz was dean of the College of Liberal Arts and Sciences at the University of Kansas, where he was also a university distinguished professor.

A nationally respected behavioral neuroscientist, Dr. Steinmetz was recognized in 1996 by the National Academy of Sciences for his contributions to the fields of experimental psychology and neuroscience. In 2012 he was named an AAAS Fellow and he is Fellow of three other societies.

His research interests include neuroanatomical and neurophysiological substrates of learning and memory; the effects of alcohol on neural and behavioral function; neurobiological and behavioral models of fetal alcohol syndrome; and the neurobiology of simple human learning, memory, and cognitive function.

Dr. Steinmetz earned his bachelor's and master's degrees at Central Michigan University and his doctorate at Ohio University. He and his wife, Sandy, have two sons and four grandchildren.

SECTION PROGRAMS
ORAL PRESENTATIONS

ORAL SESSIONS: FRIDAY 1:00-5:30

BIOLOGICAL SCIENCES SESSION 1A MEDICINE & MICROBIOLOGY AU 507
CHAIR: Grover Miller

1:00
INVESTIGATING THE ROLE OF THE DYNAMIN-LIKE PROTEIN A (DlpA) IN MITOCHONDRIAL DYNAMICS VIA CYTOSKELETAL DISRUPTION
Nicholas West. University of Central Arkansas

1:15
TARGETED THERAPY IN OVARIAN CANCER
Joseph De Soto and Frank Hahn. Philander Smith College

1:30
MITOCHONDRIAL CYP2E1 DRIVES BUTADIENE-INDUCED MITOCHONDRIAL DYSFUNCTION
Jessica H. Hartman[1]; Andres A. Caro[2]; Gunnar Boysen[1]; Grover P. Miller[1]
University of Arkansas for Medical Sciences[1]; Hendrix College[2]

1:45
GROWTH OF METHANOGENS IN THE PRESENCE OF PERCHLORATE SALTS: A STUDY FOR POSSIBLE LIFE ON MARS
John Cale; Rebecca L. Mickol; Tim A. Kral. University of Arkansas

2:00
THE EFFECT OF VARIOUS CONCENTRATIONS OF SALTS ON METHANE PRODUCTION OF METHANOGENS
Alex Chu; Rebecca Mickol: Timothy Kral. University of Arkansas

2:15
METHANOGENS AS IDEAL CANDIDATES FOR LIFE ON MARS: TOLERANCE TO PRESSURE, TEMPERATURE AND CLAYS
Rebecca L. Mickol[1]; Yuta A. Takagi[2]; Tim A. Kral[1]
University of Arkansas[1]; Oberlin College[2]

2:30
THE EFFECTS OF CELL SHAPE ON CELL FUNCTION IN AORTIC VALVE INTERSTITIAL CELLS
Ngoc Lam; Ishita Tandon; Kartik Balachandran. University of Arkansas

2:45
THE EFFECTS OF TYPE OF INFORMATION AND TYPE OF EXPOSURE ON ATTITUDES ABOUT MENTAL ILLNESS
Jessica Bonumwezi; Kelly Brice. Hendrix College

ENGINEERING & COMPUTER SCIENCE ROOM AU 508
CHAIR: David Andrews

1:00
AERO ELASTIC ANALYSIS OF BRIDGE DECK SECTIONS BY FDM USING LES: IMPROVING THE PERFORMANCE THROUGH IMPLEMENTATION OF PARALLEL COMPUTING
Blandine Kemayou[1]; R. Panneer Selvam[1]; Harold Bosch[2]
University of Arkansas[1]; FHWA/Washington[2]

1:15
COMPUTER MODEL OF TORNADO INTERACTION WITH A 2D HILL
Damaso Dominguez; R. Panneer Selvam. University of Arkansas

1:30
COMPARING TRUSS TOWERS TO A GUYED TOWER FOR POWER TRANSMISSION
A. Aliwan[1]; R. P. Selvam[1]; A. Lambert[2]
University of Arkansas[1]; Efficient Structural Solution[2]

1:45
A SUPPORT VECTOR MACHINE BASED MODEL FOR PREDICTING HEPARIN-BINDING PROTEINS USING XB PATTERNS AS FEATURES
Joseph Sirrianni; Wing Ning Li; Thallapuranam Suresh Kumar. University of Arkansas

2:00
JUST IN TIME ASSEMBLY OF ACCELERATORS FOR BIG DATA APPLICATIONS IN LARGE DATA CENTERS
Sen Ma; Zeyad Aklah; David Andrews

2:15
EXPLOITING HARDWARE ABSTRACTION FOR HYBRID PARALLEL COMPUTING FRAMEWORK
Hongyuan Ding; Miaoqing Huang. University of Arkansas

2:30
MATHEMATICAL MODELING OF BACTERIA WITH MAGNETIC
Zach Callaway; Ronghui Wang; Yanbin Li. University of Arkansas

PHYSICS SESSION 1 AU 509
CHAIR: Andy Sustich

2:00
THE PREVELANCE OF PATELLAR TENDONITIS IN MEN'S AND WOMEN'S SPORTS
Terance A. Carter and Margaret Tudor, Ph.D. Henderson State University

1:00
ELECTRON SHOCK WAVES WITH A LARGE CURRENT BEHIND THE SHOCK FRONT
Hunter Newberry; Mostafa Hemmati. Arkansas Tech University

1:15
THE EFFECT OF SPACE RADIATION AND MICROGRAVITY ON CHROMOSOME ABERRATIONS IN HUMAN ENDOTHELIAL CELLS
Cullen Shaffer[1]; Abdel Bachri[1]; Rupak Pathak[2]
Southern Arkansas University[1]; University of Arkansas for Medical Sciences[2]

1:30
TWO-DIMENSIONAL DISORDER IN BLACK PHOSPHORUS AND MONOCHALCOGENIDE MONOLAYERS AT FINITE TEMPERATURE
Mehrshad Mehboudi[1]; Salvador Barraza-Lopez[1]; Alex M. Dorio[1]; Hugh O. H. Churchill[1]; Alejandro A. Pacheco-Sanjuan[2]; Edmund O. Harriss[1]; Pradeep Kumar[1.]
University of Arkansas[1]; Universidad del Norte[2]

1:45
DOUBLE GROUPS IN MOLECULAR PHYSICS
Bradley Klee. University of Arkansas

2:00
UNIVERSAL ENERGETIC COUPLING IN COMPLEX ANTIFERROELECTRIC AND INCOMMENSURATE PEROVSKITES
Kinnary Patel[1]; Sergey Prosandeev[1,2]; Yurong Yang[1]; Bin Xu[1]; Jorge Ìñiguez[3]; L. Bellaiche[1]
University of Arkansas[1]; Southern Federal University, Russia[2]; Luxembourg Institute of Science and Technology[3]

2:15
QUANTUM CORRELATIONS OF TWO AND THREE QUANTUM DOTS IN A DRIVEN CAVITY
Willa Rawlinson; Reeta Vyas. University of Arkansas

2:30
A RELATIVISTIC APPROACH TO KINETIC AND CANONICAL ELECTROMAGNETIC SYSTEMS
Cheyenne J. Sheppard; Brandon A. Kemp

SPECIAL BOTANY SESSION 1 AU 510
ORGANIZED BY Johnnie Gentry
CHAIRED BY Travis D. Marsico

1:00
A TRIBUTE TO DR. GEORGE PRYOR JOHNSON, SUMMARIZING HIS CONTRIBUTIONS TO ARKANSAS BOTANY AND MY LIFE
Travis D. Marsico. Arkansas State University

1:15
THE STATUS OF TWO LARGE NON-NATIVE INVASIVE GRASSES IN ARKANSAS
C. Theo Witsell. Arkansas Natural Heritage Commission

1:30
UNDERSTANDING VASCULAR PLANT DIVERSITY IN AN AGRICULTURE-DOMINATED COUNTY IN NORTHEASTERN ARKANSAS
Jennifer N. Reed; Travis D. Marsico. Arkansas State University

1:45
PATTERNS OF PLANT SPECIES RICHNESS ACROSS FOREST-WETLAND ECOTONES IN THE ALLEGHENY MOUNTAINS OF WEST VIRGINIA
Karen L. Willard; Steven L. Stephenson. University of Arkansas

2:00
PHYLOGEOGRAPHY OF JEFFREY PINE IN THE KLAMATH MOUNTAINS
Julia Lefler; Ann Willyard. Hendrix College

2:15
MITOCHONDRIAL LINEAGES OF PINUS PONDEROSA S.L. IN THE USA AND RELATED SPECIES IN MEXICO AND CENTRAL AMERICA
Hassan Hussein Karemera; Ann Willyard. Hendrix College

2:30
PLANT PHENOLOGICAL DATA FOR CENTRAL ARKANSAS; MAKING PREDICTIONS ABOUT CLIMATE CHANGE
Nicholas T. Dial; Emily A. Roberts; Katherine C. Larson
University of Central Arkansas

2:45
DNA SEQUENCE ANALYSIS OF FRESHWATER EUSTIGMATOPHYCEAE FROM DIVERSE LOCATIONS REVEALS EXCITING NEW TAXA
M. Cardona-Otero; L.A. Morgan; M.W. Fawley; K.P. Fawley.
University of Arkansas at Monticello

GEOSCIENCE SESSION 1 AU 511
CHAIR: Walter Manger

1:00
IMPACT OF CLIMATE VARIATIONS ON SOYBEAN YIELD IN EAST ARKANSAS: 1960-2014
J. W.Magugu; S. Feng; Q. Huang. University of Arkansas

1:15
CLIMATIC AND STAKEHOLDER RELATIONSHIP WITH GROUNDWATER SECURITY IN ARKANSAS
Christopher A. Craig. University of Arkansas

1:30
PLAIN FACTS ABOUT GLOBAL CLIMATE CHANGE AND GLOBAL WARMING
Malcolm Cleaveland. University of Arkansas

1:45
SEDIMENTATION IN THE UPPER REACHES OF LAKE OUACHITA
Jason A. Patton. Arkansas Tech University

2:00
NEAR-SURFACE SEISMIC INVESTIGATIONS OF MISSISSIPPIAN OUTCROPS AT PEDRO ARKANSAS
Matthew Ruggeri; Chris Liner. University of Arkansas

2:15
GEOCHEMICAL PROCESSES AND CONTROLS AFFECTING WATER QUALITY OF THE KARST AREA OF BIG CREEK NEAR MT. JUDEA, ARKANSAS
Van Brahana[1]; Joe Nix[2]; Clark Kuyper[2]; Teresa Turk[3]; Carol Bitting[4];Katarina Kosic Ficco[5]; Ray Quick[6]; Brian Thompson[7]; John Murdoch[1]
University of Arkansas[1]; Ouachita Baptist University[2]; National Oceanic and Atmospheric Association (retired)[3]; Field Coordinator-Karst Hydrogeology of Buffalo Nat.River[4]; Univ. of Nova Gorica Slovenia[5]; Woodward Clyde Consulting Group (retired); ADEQ (retired)[6]; Tyson Foods[7]

2:30
PALEOZOIC SANDSTONE RECORD, SOUTHERN OZARKS REGION: DEPOSITIONAL CHARACTER AND HISTORY
Elvis Bello; Walter L. Manger. University of Arkansas

ENGINEERING SESSION 1 AU 512
CHAIR: Daniel Bullock

1:00
PERSISTENT AND CONTROLLABLE WEATHER BALLOONS AS HIGH ALTITUDE TEST VEHICLE
Maxwell Martin; Adam Huang. University of Arkansas

1:15
PROGRESS ON THE DEVELOPMENT OF AN ACTIVE DEORBITER SUBSYSTEM FOR SMALL SATELLITES
Morgan Roddy; Adam Huang. University of Arkansas

1:30
AQUEOUS PROPYLENE GLYCOL SOLUTION CHARACTERIZATION FOR COLD GAS THRUSTER DEVELOPMENT
John Lee; Adam Huang. University of Arkansas

1:45
TIME-OF-FLIGHT BASED SONIC SPEED MEASUREMENTS FOR COLD GAS THRUSTER DEVELOPMENT
John Lee; Brandon Kempf; Adam Huang. University of Arkansas

2:00
SIMULATION AND DESIGN OF MINIATURIZED RESONANT MICROWAVE CAVITIES FOR USE IN Q-THRUSTERS
Joshua Pennington; Adam Huang. University of Arkansas

2:15
OPTIMAL DESIGN OF PHOTOACOUSTIC CELL BASED ON COMSOL SIMULATION
Aiping Li[1]; Simon. S. Ang[2]; Xunli Zhang[1]; Haikuo Gao[1]; Jun Chang[3]; Qiang Wang[3]
Binzhou University[1]; University of Arkansas[2]; Shandong University[3]

2:30
QUANTIFYING THE BENEFITS OF CONTINUOUS REPLENISHMENT PROGRAM FOR PARTNER SELECTION
Payam Parsa; Manuel Rossetti; Shengfan Zhang. University of Arkansas

2:45
NEW TECHNIQUES TO IMPROVE THE OPERATION OF PROSTHETIC LIMBS DURING MUSCLE FATIGUE
Hamdi Albunashee[1]; Ghulam Rasool[2]; Kamran Iqbal[1]
University of Arkansas at Little Rock[1]; Rehabilitation Institute of Chicago[2]

BIOLOGICAL SCIENCES SESSION 2A: VERTEBRATES AU 507
CHAIR: Brian Wagner

3:30
HISTORY AND CURRENT STATUS OF THE NORTHERN SAW-WHET OWL IN ARKANSAS
Mitchell Pruitt; Kimberly Smith. University of Arkansas

3:45
IMPACTS OF MAN-MADE STRUCTURES ON AVIAN COMMUNITY METRICS IN 4 STATE PARKS IN NORTHWESTERN ARKANSAS
Ryan D. Keith[1]; Bennett P. Grooms[1]; Rachael E. Urbanek[2]
Arkansas Tech University[1]; University of North Carolina, Wilmington[2]

4:00
IMPACTS OF SHALE GAS DEVELOPMENT ON BREEDING BIRDS IN THE EASTERN UNITED STATES
Kevin J. Krajcir; Annie Meek; Matthew D. Moran; Maureen R. McClung.
Hendrix College

4:15
SEED PREFERENCE OF THE EASTERN GRAY SQUIRREL (SCIURUS CAROLINENSIS) IN RELATION TO THE SEED DISPERSION OF OSAGE ORANGE (MACLURA POMIFERA)
Jessa H. Thurman; Ginny Mitchell; Serena Murphy; Charli N. Davis ; Hannah Smashey; Matthew D. Moran; Jennifer L. Penner
Hendrix College

4:30
OTOLITH AGING OF THE LARGEMOUTH BASS, MICROPTERUS SALMOIDES, AS A MANAGEMENT TOOL FOR FISHERIES MANAGERS AT NORTH FORK LAKE
Jess Kelly; Julie Stanley. Ouachita Baptist University

4:45
LONG-TERM MONITORING AND RECOVERY OF A POPULATION OF ALLIGATOR SNAPPING TURTLES, MACROCHELYS TEMMINCKII (TESTUDINES: CHELYDRIDAE), FROM A NORTHEASTERN ARKANSAS STREAM
Stanley E. Trauth[1]; Dustin S. Siegel[2]; Malcolm L. McCallum[3]; David H. Jamieson[4]; Joy B. Trauth[1]; Hilary Hicks1; Jonathan W. Stanley[1]; Jonathan Elston[5]; John J. Kelly[6]; Johnny D. Konvalina[1]
Arkansas State University[1]; Southeast Missouri State University[2]; Scientific Investigator's Alliance, Inc.[3]; Crowder College-Cassville, MO[4]; Dallas, TX[5]; Richmond Heights, MO[6]

5:00
FOOD HABITS OF GREEN TREEFROGS (HYLA CINEREA) FROM ARKANSAS
Christopher Thigpen; Holly Dodson; Stanley Trauth
Arkansas State University

5:15
VERTEBRATE NATURAL HISTORY NOTES FROM ARKANSAS, 2016
Renn Tumlison[1]; Chris T. McAllister[2]; Henry W. Robison[3]; Matt B. Connior[4]; D. Blake Sasse[5]; David A. Saugey[6]; Steve Chordas III[7]
Henderson State University[1]; Eastern Oklahoma State College[2]; Southern Arkansas University[3]; Northwest Arkansas Community College[4]; Arkansas Game and Fish Commission[5]; Nightwing Consulting[6]; Ohio State University[7]

BIOLOGICAL SCIENCES 2B: PLANTS & FISHES AU 508
CHAIR: Doug Barron

3:30
PHENOTYPIC VARIATION OF A SEGREGATING BLACKBERRY POPULATION FOR MOLECULAR MARKER DEVELOPMENT
Loren M. Anthony; John R. Clark; Daniela Segantini
University of Arkansas

3:45
THE EFFECTS OF SHADE ON GREENHOUSE-GROWN PRIMOCANE FRUITING BLACKBERRIES
Olivia Caillouet; Curt Rom; Jason McAfee. University of Arkansas

4:00
EVALUATION OF HARVEST TIME/TEMPERATURE ON POSTHARVEST INCIDENCE OF RED DRUPELET REVERSION DEVELOPMENT AND FIRMNESS OF BLACKBERRY (RUBUS L. SUBGENUS RUBUS WATSON)
Jack E. McCoy; John R. Clark; Alejandra A. Salgado
University of Arkansas

4:15
ALLELOPATHIC INFLUENCE OF EUCALYPTUS ON THREE COMMON KENYAN FARMING CROPS
Brandy Garrett Kluthe. University of Arkansas

4:30
YEAST ECOLOGY OF ARKANSAS WINE FERMENTATIONS
Alex Crocker. Hendrix College

4:45
GTP HYDROLYSIS IS NOT REQUIRED BY CHLOROPLAST SIGNAL RECOGNITION PARTICLE AND ITS RECEPTOR FOR POST TRANSLATIONAL TARGETING AND INSERTION OF INTEGRAL THYLAKOID MEMBRANE PROTEINS
Priyanka Sharma; Ralph L. Henry; Robyn L. Goforth; Alicia D. Kight
University of Arkansas

5:00
DOES THE NATIVE GEOGRAPHIC ORIGIN OF AN INVADER AFFECT STREAM STRUCTURE AND FUNCTION?
Nicole E. Graham[1]; Daniel D. Magoulick[2]
University of Arkansas[1]; University of Arkansas/USGS[2]

5:15
LOTIC SMALLMOUTH BASS BODY CONDITION CHANGES INDUCED BY SEASONAL DRYING
Christopher R. Middaugh; Daniel D. Magoulick
University of Arkansas

CHEMISTRY SESSION AU 509
CHAIR: Dennis Provine

3:30
NEW GENERAL RELATIONSHIP BETWEEN BOND VALENCE (ORDER) AND BOND LENGTH
Franklin D. Hardcastle. Arkansas Tech University

3:45
LENGTH–VALENCE RELATIONSHIP FOR CARBON–NITROGEN CHEMICAL BONDS
Connor Harris; Franklin D. Hardcastle. Arkansas Tech University

4:00
EVIDENCE FOR A NEW PHASE OF LIQUID BURIED IN EXPERIMENTAL SURFACE TENSION MEASUREMENTS OF SUPERCOOLED WATER
Ryan Rogers; Kai-Yang Leong; Feng Wang. University of Arkansas

4:15
SMALL MOLECULE INHIBITORS OF SYSTEM xC
John Kreun; Allen Snider; Mariusz P. Gajewski.
Arkansas Tech University

4:30
VARIED APPROACHES TO THE IONIZATION BEHAVIOR OF SPECIFIC GLU RESIDUES THAT FACE THE LIPIDS IN TRANSMEMBRANE HELICES
Venkatesan Rajagopalan; Denise V. Greathouse; Roger E. Koeppe II
University of Arkansas

4:45
CHOLESTEROL INFLUENCE ON ARGININE-CONTAINING TRANSMEMBRANE PEPTIDES
Jordana K. Thibado; Ashley Martfeld; Denise Greathouse; Roger Koeppe.
University of Arkansas, Fayetteville

5:00
CONCENTRATION OF PLANT VOLATILES FOR ANALYSIS USING GC/MS
Lance Benson; Edmond Wilson. Harding University

5:15
STEREOSPECIFIC REDUCTION OF R- AND S- WARFARIN BY HUMAN HEPATIC CYTOSOLIC REDUCTASE
D. A. Barnette[1]; D. L. Pouncey[2]; R Nshimiyimana[2]; L. P. Desrochers[2]; D.K. Hammon[2]; T. E. Goodwin[2], G. P. Miller[1]
University of Arkansas for Medical Sciences[1]; Hendrix College[2]

5:30
MULTI-ELEMENT ANALYSIS OF HERSHEY'S CHOCOLATE AND TINFOIL WRAPPERS USING INDUCTIVELY COUPLED PLASMA MASS SPECTROMETRY TO STUDY HEAT'S EFFECT OF LEACHING METALS INTO CHOCOLATE
Alexis Donaway; Dennis Province. Harding University

BOTANY SPECIAL SESSION 2 AU 510
ORGANIZED BY Johnnie Gentry
CHAIRED BY Travis D. Marsico

3:30
A TEST OF PHYLOGENY FOR TRIBE ASTEREAE (ASTERACEAE) USING SINGLE-COPY NUCLEAR DNA SEQUENCE
Shelby Clark; Richard Noyes. University of Central Arkansas

3:45
A MICROHABITAT ANALYSIS OF THREE INVASIVE PLANTS IN THE OZARKS
Eric Hearth . University of Arkansas

4:00
MENDELIAN INHERITANCE OF PARTHENOGENETIC EMBRYO FORMATION IN FLEABANES (ERIGERON; ASTERACEAE)
Richard D. Noyes. University of Central Arkansas

4:15
EXTRAORDINARY DIVERGENCE OF THE ALGA NANNOCHLOROPSIS (EUSTIGMATOPHYCEAE) UPON TRANSITION FROM MARINE TO FRESHWATER
M.W. Fawley; K.P. Fawley. University of Arkansas at Monticello

4:30
ARE ERYTHRONIUM SPECIMENS FROM THE INTERIOR HIGHLANDS INTERMEDIATES BETWEEN E. ALBIDUM AND E. MESOCHOREUM?
K.P. Fawley[1]; C.T. Witsell[2]; M.W. Fawley[1]
University of Arkansas at Monticello[1]; Arkansas Natural Heritage Commission[2]

GEOSCIENCES SESSION 2 AU 511
CHAIR: Van Brahana

3:30
LITHOSTRATIGRAPHIC SUCCESSION AND DEPOSITIONAL DYNAMICS, LOWER MISSISSIPPIAN SUCCESSION, SOUTHERN OZARKS, NORTHERN ARKANSAS AND ADJACENT AREAS
Forrest McFarlin. University of Arkansas

3:45
GS-CARBON SEQUESTRATION AT PEA RIDGE NATIONAL MILITARY PARK IN NW ARKANSAS FROM A TERRESTRIAL/BIOLOGICAL PERSPECTIVE.
Dorine Reed Bower. University of Arkansas

4:00
3D SEISMIC INTERPRETATION OF SUBSURFACE EASTERN ARKOMA BASIN BELOW THE MISSISSIPPIAN-PENNSYLVANIAN BOUNDARY IN CONWAY COUNTY, ARKANSAS
Daniel Moser. University of Arkansas

4:15
SEQUENCE STRATIGRAPHY OF THE ST JOE AND BOONE FORMATIONS, LOWER MISSISSIPPIAN (KINDERHOOKIAN-OSAGEAN), SOUTHERN OZARK REGION
Sean C. Kincade. University of Arkansas

4:30
COMPARISON OF THE ELEMENTAL GEOCHEMISTRY OF THE BOONE CHERT AND THE ARKANSAS NOVACULITE
John Philbrick. University of Arkansas

4:45
BORON AND CHLORIDE RATIOS THROUGH TIME IN THE TAUPO VOLCANIC ZONE, NEW ZEALAND: A CASE STUDY IN CONTINUAL MONITORING FOR ASSESSING DEVELOPMENT IMPACTS IN HYDROTHERMAL SYSTEMS
Joshua M. Blackstock; Phillip D. Hays. University of Arkansas

5:00
ASSESSING THE AUTHENTICITY OF STABLE ISOTOPE COMPOSITIONS IN VERTEBRATE SKELETAL REMAINS: IMPLICATIONS FOR PALEOCLIMATIC INTERPRETATION OF

THE UPPER CRETACEOUS KAIPAROWITS FORMATION, SOUTHERN UTAH
Daigo Yamamura; Celina A. Suarez. University of Arkansas

ENGINEERING SESSION 2 AU 512
CHAIR: Wei Du

3:30
CHARACTERIZATION OF SILICON PHOSPHORUS ALLOY FOR DEVICE APPLICATIONS
Larry Cousar; Hameed Naseem. University of Arkansas

3:45
EFFECT OF QUINHYDRONE-METHANOL PASSIVATION ON HYDROGENATED AND STANDARD BORON EMITTERS
Matthew Young; Hameed Naseem. University of Arkansas

4:00
ELECTROSPUN POLY-ETHYLENE OXIDE NANOFIBERS
Hope Schneider; Daniel Bullock; Jim Steuber. Arkansas Tech University

4:15
ENGINEERING BIPHASIC JANUS-TYPE POLYMER-PROTEIN NANOFIBERS VIA CENTRIFUGAL JET SPINNING
Prashanth Ravishankar; Alex Khang; Kartik Balachandran.
University of Arkansas

4:30
CHARACTERIZING NANOPARTICLE SIZE BY DYNAMIC LIGHT SCATTERING (DLS)
Marzia Zaman; Dr. Simon Ang; Surendra Singh. University of Arkansas

4:45
A COMPARATIVE STUDY FOR THE MECHANICAL PROPERTIES OF 3D PRINTED PLASTIC PARTS
Mahbub Ahmed; Md. Rashedul Islam; Justin Vanhoose.
Southern Arkansas University

5:00
BIOMASS SUSPENSION FOR LANDFILLS: A SUSTAINABLE WASTE MANAGEMENT APPROACH
Rajesh Sharma; Keith Arnoult; Kevin Hart. Arkansas State University

5:15
ENVIRONMENTAL SUSTAINABILITY OF DISTRIBUTION-RETAIL NETWORKS IN THE UNITED STATES
Jasmina Burek; Darin Nutter. University of Arkansas

<u>ORAL SESSIONS: SATURDAY 8:00-10:00</u>

BIOLOGICAL SCIENCES SESSION 3A: INVERTEBRATES
Bell 2291
CHAIR: Abraham Tucker

8:00
ROAD WARRIORS: INVESTIGATING HABITAT USE BY TWO ENDEMIC PRIMARY-BURROWING CRAYFISHES
Cody Rhoden[1]; Chris Taylor[1]; Brian Wagner[2]
INHS – Univ. of Illinois[1]; Arkansas Game & Fish Commission[2]

8:15
NOTES AND NEW RECORDS OF THE NATURAL HISTORY OF SELECTED INVERTEBRATES FROM ARKANSAS
Renn Tumlison[1]; Henry W. Robison[2]; Terry L. Tumlison[1]
Henderson State University[1]; Southern Arkansas University[2]

8:30
GENOME-WIDE ANALYSIS OF SEXUAL AND ASEXUAL DAPHNIA PULEX MUTATION ACCUMULATION LINES
Abraham Tucker[1]; Nathan Keith[2]; Michael Lynch[2]
Southern Arkansas University[1]; Indiana University[2]

8:45
THE LARGE WOLF SPIDER RABIDOSA RABDIA (ARANEAE: LYCOSIDAE) DOES NOT REQUIRE VENOM TO CAPTURE PREY OF A COMMON SIZE
Ryan Stork; Sara Wilmsen. Harding University

9:00
OVEREXPRESSION OF B-TOXIN AS SEEN IN CENRUROIDES VITTATUS
Jacob Pinkerton; Hayden Scott; T. Yamashita
Arkansas Tech University

9:15
OVEREXPRESSION OF CENTRUROIDES VITTATUS B-TOXIN
Donald McCormick; Zachary Schwartz; T. Yamashita
Arkansas Tech University

9;30
QUANTIFYING SODIUM TOXIN GENE ACTIVITY IN THE SCORPION, CENTRUROIDES
Cody Chivers; Aimee Bowman. Arkansas Tech University

BIOLOGICAL SCIENCES 3B: INSECTS & ECOLOGY
Bell 2273
CHAIR: Jess Kelly

8:00
DNA BARCODING CONFIRMATION OF THE FIRST RECORD OF THE AMERICAN BURYING BEETLE, NICROPHORUS AMERICANUS, IN CLARK COUNTY, ARKANSAS
Jess Kelly. Ouachita Baptist University

8:15
AN ADULT FEMALE MOSQUITO SURVEY IN SOUTHWEST MISSOURI IN 2014
Olivia E. Jamieson[1]; Joanna Moreland[2]; David H. Jamieson[2]
University of Arkansas[1]; Crowder College[2]

8:30
INDIRECT EFFECTS OF LEAF-CUTTER ANTS ON THE LITTER ARTHROPOD COMMUNITY IN A TROPICAL RAINFOREST
Rachel Wells[1]; Serena Murphy[2]; Matthew Moran[1]
Hendrix College[1]; University of Georgia, Costa Rica[2]

8:45
A PRELIMINARY REPORT ON INSECTS INHABITING OAK-PINE SAND HABITATS IN THE WEST GULF COASTAL PLAIN DIVISION OF ARKANSAS
Peter W. Kovarik[1]; Matthew B. Connior[2]; Steven W. Chordas III[3]; Henry W. Robison[4] Paul E. Skelley[5]
Columbus State Community College[1]; Northwest Arkansas Community College[2]; Ohio State University[3]; Southern Arkansas University[4]; Florida State Collection of Arthropods[5]

9:00
BISON WALLOWING EFFECTS ON THE ARTHROPOD COMMUNITY IN A TALLGRASS PRAIRIE
Zachary Nickell; Matthew Moran. Hendrix College

9:15
WHAT'S IN THE WATER? RESULTS FROM E. COLI INVESTIGATIONS FROM SELECTED TRIBUTARIES OF BIG CREEK, NEWTON CO. ARKANSAS.

Teresa Turk[1]; Carol Bitting[2]; Van Brahana[3]
NOAA, Research Fisheries Biologist, Retired[1]; Field Coordinator, KHBNRP[2]; University of Arkansas[3]

9:30
RELATIVE WILDLIFE COMMUNITY METRICS WITHIN ARKANSAS STATE PARKS
Bennett Grooms[1]; Rachael Urbanek[2]
Arkansas Tech University[1]; University of North Carolina Wilmington[2]

9:45
LAND USE CHANGES FROM UNCONVENTIONAL GAS DEVELOPMENT IN PUBLIC LANDS OF THE FAYETTEVILLE SHALE
A.Brandon Cox; Nathan T. Taylor; Mimi A. Rebein. Hendrix College

BIOLOGICAL SCIENCES 3C: PARASITES Bell 2282
CHAIR: James Daly

8:00
THE TICKS (ARACHNIDA: ACARI: IXODIDA) OF ARKANSAS
Chris T. McAllister[1]; Lance A. Durden[2]; Henry W. Robison[3]
Eastern Oklahoma State College[1]; Georgia Southern University[2]; Southern Arkansas University[3]

8:15
THE ACANTHOCEPHALANS OF ARKANSAS, WITH NEW HOST AND GEOGRAPHIC DISTRIBUTION RECORDS FROM FISHES
Chris T. McAllister[1]; Dennis J. Richardson[2]; Michael A. Barger[3]; Thomas J. Fayton[4]; Henry W. Robison[5]
Eastern Oklahoma State College[1]; Quinnipiac University[2]; Peru State College[3]; University of Southern Mississippi[4]; Southern Arkansas University[5]

8:30
GEOGRAPHIC DISTRIBUTION RECORDS OF MACRACANTHORHYNCHUS INGENS (ARCHIACANTHOCEPHALA: OLIGACANTHORHYNCHIDAE) FROM THE RACCOON, PROCYON LOTOR, IN NORTH AMERICA
Dennis J. Richardson[1]; Alex Leveille[2]; Aniruddha V. Belsare[3]; Harith S. Al-Warid[3]; Matthew E. Gompper[3]
Quinnipiac University[1]; University of Guelph[2]; University of Missouri, Columbia[3]

8:45
TUNGIASIS IN A TRAVELER RETURNING FROM CAMEROON, AFRICA
Dennis J. Richardson; Alexi M. Mangili. Quinnipiac University

9:00
PREVALENCE AS A PREDICTOR OF OTHER HELMINTH POPULATION DESCRIPTORS (MEAN, STANDARD DEVIATION, MAXIMUM NUMBER) IS RELATIVELY INACCURATE AT HIGH PARASITE DENSITIES IN THE HOSTS
James J. Daly Sr.; Kenneth Wagner
University of Arkansas for Medical Sciences

9:15
PROPORTIONALITY BETWEEN POPULATION DESCRIPTORS (COVARIABLES) IN AN AGGREGATED ACANTHOCEPHALAN (HELMINTH) INFECTION OF A MICROCRUSTACEAN HOST: CROFTON; HYNES AND NICHOLAS REVISITED
James J. Daly Sr.; Kenneth Wagner
University of Arkansas for Medical Sciences

9:30
EVALUATING THE ROLE OF HOST BEHAVIOR IN DETERMINING RISK OF VECTOR-BORNE DISEASE
Douglas G. Barron[1]; Ahmet K. Uysal[2]; Toru Shimizu[2]; Nathan D Burkett-Cadena[3]; Lynn B. Martin[2].
Arkansas Tech University[1]; University of South Florida[2]; University of Florida[3]

9:45
DIVERSITY OF ECTOMYCORRHIZAL FUNGI ASSOCIATED WITH WHITE OAK (QUERCUS ALBA L.) IN NORTHWEST ARKANSAS
Mourad Ben Hassine Ben Ali[1]; Brandy Garrett Kluthe[1]; Brandy Garrett Kluthe[1]; S L Stephenson[1]; T Collins[2]
University of Arkansas[1]; Fire and Resource Management, National Park Service, Buffalo National River, Harrison, Arkansas[2]

GEOSCIENCES SESSION 3 Bell 2269
CHAIR: Francis Umesiri

8:00
DEPOSITIONAL DYNAMICS AND EARLY CEMENTATION HISTORY OF THE SHORT CREEK OOLITE MEMBER, BOONE FORMATION (OSAGEAN, LOWER MISSISSIPPIAN), NORTHERN ARKANSAS
Kevin Jayne[1]; Angela Chandler[2]; Walter Manger[1]
University of Arkansas[1]; Arkansas Geological Survey[2]

8:15
LOWER MISSISSIPPIAN CHERT DEVELOPMENT, SOUTHERN MIDCONTINENT REGION
Julie M. Cains. University of Arkansas

8:30
SOURCING DIAGENETIC AND MINERALIZING FLUIDS OF MISSISSIPPI VALLEY-TYPE ORES ALONG THE CINCINNATI ARCH
William Travis Garmon; Adriana Potra; Andrew H. Wulff.
University of Arkansas

8:45
TOXIC EFFECTS OF METALS ON MICROBIAL ORGANIC CARBON TRANSFORMATION AND NITRATE REMOVAL
Victor L. Roland II; Asher Sampong; Erik Pollock; Phillip D. Hays.
University of Arkansas

9:00
A FIRST STEP IN MODELING CAVE FORMATION IN TURBULENT FLOW
Max Cooper; Matt Covington. University of Arkansas

9:15
ESTABLISHING THE AGE AND CORRELATION OF THE MOOREFIELD SHALE (MISSISSIPPIAN) IN ITS TYPE AREA, NORTHEASTERN ARKANSAS
Obiora Dalu; Walter L. Manger. University of Arkansas

9:30
THE CALORIC OUTPUT OF GLOBAL AGRICULTURE, 1961-2012
Quinn Montana; Steve Boss. University of Arkansas

ENGINEERING SESSION 3 Bell 2267
CHAIR: Abdel Bachri

8:00
ANDROID CONTROL OF SCIENCE INSTRUMENTS
Daniel Grant; Maria Medrano; Edmond Wilson. Harding University

8:15
THE PROPOSED STATEWIDE TRAFFIC MANAGEMENT CENTER: A UALR PERSPECTIVE
Yupo Chan. University of Arkansas at Little Rock

8:30
AN OVERVIEW OF AN UNDERGRADUATE AND GRADUATE FABRICATION LABORATORY FOR SILICON SOLAR CELLS
Matthew Young; Larry Cousar; Fahimeh Banihashemian; Hameed Naseem.
University of Arkansas

8:45
ADDITIVE MANUFACTURING: A TOOL TO IMPROVE THE SYNERGY BETWEEN TEACHING AND RESEARCH
Matthew Watters; Nice Kaneza; Michelle L. Bernhardt.
University of Arkansas

9:00
DEVELOPMENT OF A LOW-COST 'LUMPED SYSTEM' EXPERIMENT SETUP FOR AN ENGINEERING LABORATORY COURSE
Mahbub Ahmed[1]; Lionel Hewavitharana[1]; Kendra Ahmed[1]; Md. Rashedul Islam[1]; Mamunur Rashid[2]
Southern Arkansas University[1]; Indiana University Purdue University Fort Wayne[2]

9:15
MILD TRAUMATIC BRAIN INJURY RESULTED IN INCREASED AQUAPORIN-4 EXPRESSION – RELEVANCE TO POST INJURY EDEMA
Nasya Sturdivant. University of Arkansas

10-10:30am Special Lecture BELL 2291

CHANGING HIS MIND AT THE SPEED OF THOUGHT: EINSTEIN'S FAILED ATTEMPTS TO UNDISCOVER GRAVITATIONAL WAVES
Daniel John Kennefick University of Arkansas

Although Albert Einstein gave the first concrete description of gravitational waves known to Physics, he was nevertheless on more than one occasion very skeptical of their existence. This talk discusses his changing views on the subject and tells the story of his abortive 1936 attempt to disprove their existence which led him to angrily withdraw a paper form the Physical Review after receiving a critical referee's report.

POSTER PRESENTATIONS

BIOLOGICAL SCIENCES POSTER PRESENTATIONS

BiP-1. REPORT ON A FUNGAL-LIKE INFECTION (Oomycota) IN NORTHERN STUDFISH, *Fundulus catenatus* (Fundulidae) FROM TENMILE CREEK, SALINE COUNTY, ARKANSAS
Chris T. McAllister[1]; Henry W. Robison[2]
Eastern Oklahoma State College[1]; Southern Arkansas University[2]

BiP-2. AN *Epistylus* sp. (Ciliophora: Peritrichia: Epistylididae) INFESTATION ON GREEN SUNFISH, *Lepomis cyanellus* (Perciformes: Centrarchidae), FROM ARKANSAS
Chris T. McAllister[1]; Henry W. Robison[2]; Stanley E. Trauth[3]
Eastern Oklahoma State College[1]; Southern Arkansas University[2]; Arkansas State University[3]

BiP-3. GASTROINTESTINAL PARASITES OF THE NORTHERN RIVER OTTER, *Lontra canadensis* (Carnivora: Mustelidae) FROM ARKANSAS
Chris T. McAllister[1]; Allison Surf[2]; Renn Tumlison[2]; Charles R. Bursey[3]; Thomas J. Fayton[4]
Eastern Oklahoma State College[1]; Henderson State University[2]; Pennsylvania State University[3]; University of Southern Mississippi[4]

BiP-4. HEMATOZOAN PARASITES (Apicomplexa: Haemogregarinidae, Hepatozoidae) OF SIX ARKANSAS REPTILES (Testudines, Ophidia)
Chris T. McAllister[1]; Matthew B. Connior[2]; Henry W. Robison[3]; Thomas J. Fayton[4]; Renn Tumlison[5]; Stanley E. Trauth[6]
Eastern Oklahoma State College[1]; Northwest Arkansas Community College[2]; Southern Arkansas University3; University of Southern Mississippi[4]; Henderson State University[5]; Arkansas State University[6]

BiP-5. NEW RECORDS OF CHIGGERS FROM ARKANSAS AMPHIBIAN AND REPTILES
Matthew B Connior[1]; Chris T. McAllister[2]; Lance A. Durden[3]
Northwest Arkansas Community College[1]; Eastern Oklahoma State University[2]; Georgia Southern University[3]

BiP-6. NEW DISTRIBUTIONAL RECORDS OF THE OHIO SHRIMP, *Macrobrachium ohione* SMITH (Decapoda: Palaemonidae) IN ARKANSAS
Henry W. Robison[1]; Lindsey Lewis[2]; Casey Cox[3]; Geoffry Spooner[4]; Reid Adams[4]; Chris T. McAllister[5]
Southern Arkansas University[1]; US Fish & Wildlife Service[2]; Arkansas Game & Fish Commission[3]; University of Central Arkansas[4]; Eastern Oklahoma State College[5]

BiP-7. **OCCURRENCE OF SHOAL CHUB, *Macrhybopsis hyostoma* (CYPRINIFORMES: CYPRINIDAE) IN AN UNUSUAL HABITAT IN THE ARKANSAS RIVER SYSTEM OF ARKANSAS: COULD DIRECT TRIBUTARIES BE REFUGIA ALLOWING PERSISTENCE DESPITE FRAGMENTATION OF INSTREAM HABITAT?**
Jobi A. Brown[1]; Henry W. Robison[2]; Chris T. McAllister[3]
USDA Forest Service[1]; Southern Arkansas University[2]; Eastern Oklahoma State University[3]

BiP-8. A NEW HOST RECORD FOR THE BAT BUG, *Cimex adjunctus* (Insecta: Hemiptera) FROM EASTERN SMALL-FOOTED MYOTIS, *Myotis leibii* (Chiroptera: Vespertilionidae), IN ARKANSAS
D. Blake Sasse[1]; Chris T. McAllister[2]; Lance A. Durden[3]
Arkansas Game and Fish Commission[1]; Eastern Oklahoma State College[2]; Georgia Southern University[3]

BiP-9. FIRST RECORD OF THE OPOSSUM SHRIMP, *Mysis diluviana* (Crustacea: Mysida) FROM ARKANSAS
Kevin Schanke[1]; Henry Robison[2]; Nathan J. Wentz[1]; Chris T. McAllister[3]
Arkansas Department of Environmental Quality[1]; Southern Arkansas University[2]; Eastern Oklahoma State College[3]

BiP-10. A CASE OF AN ANT (*Crematogaster* sp.) EMBEDDED WITHIN THE SKIN OF A GREEN TREEFROG (*Hyla cinerea*) FROM NORTHEASTERN ARKANSAS
Christopher Thigpen; Stanley Trauth.
Arkansas State University

BiP-11. POPULATION DYNAMICS OF CHELONIANS IN AN URBAN LAKE IN JONESBORO, CRAIGHEAD COUNTY, ARKANSAS
J.D. Konvalina; C.S. Thigpen; S.E. Trauth .
Arkansas State University

BiP-12. NEW HOST AND COUNTY RECORDS OF LEECH (*Cystobranchus klemmi*, Hirudinida: PiscicolidaE) PARASITSM ON A VULNERABLE ENDEMIC DARTER, *Etheostoma pallididorsum* (Percidae), IN ARKANSAS
Christopher Thigpen; Brittany McCall; Brook Fluker. Arkansas State University

BiP-13. MEIOFAUNA COLONIZATION OF ARTIFICIAL POOLS IN AN OZARK GRAVEL BED STREAM
Laura Berryman; Arthur Brown. University of Arkansas

BiP-14. RECOLONIZATION OF MEIOFAUNA AFTER PHYSICAL DISTURBANCE IN A GRAVEL BED STREAM
Melissa Welch; Laura Berryman; Art Brown. University of Arkansas

BiP-15. GEOGRAPHIC RANGE OF THE WESTERN HARVEST MOUSE (*Reithrodontomys megalotis*) IN ARKANSAS
Gary Graves. Smithsonian Institution

BiP-16. MORPHOLOGICAL DIVERSITY OF ECTOMYCORRHIZAE ASSOCIATED WITH WHITE OAK, BLACK OAK AND CHINQUAPIN IN NORTHWEST ARKANSAS.
Ndotimi J. Apulu; Mourad B. Hassine; Steve Stephenson;
Brandy Garrett Kluthe. University of Arkansas

BiP-17. UNUSUAL CONCENTRATION OF SUMMER TANAGERS IN NORTHWESTERN ARKANSAS DURING WINTER 2015-2016
Kimberly G. Smith; Joseph C. Neal; Michael Mlodinow.
University of Arkansas

BiP-18. AN ECOLOGICAL STUDY OF THE BURROWING AND FEEDING HABITS OF *Coronis scolopendra* Latreille (Stomatopoda: Nannosquillidae)
Addison Ochs. Southern Arkansas University

BiP-19. FIBER TYPE PROFILES OF THE NASAL MUSCULATURE OF THE HARBOR PORPOISE (*Phocoena phocoena*)
Megan Murphy[1]; Jennifer L. Dearolf[1]; Nicole M. Thometz[2]
Hendrix College[1]; University of California Santa Cruz[2]

BiP-20. ENVIRONMENT INFLUENCES SURVIVAL OF *Caenorhabditis elegans* EXPOSED TO LONG-TERM SEVERE HYPOXIA
Karah Broaddus, Emily Brown, Lindsey Chessor, Lane Dailey, McKenzie Evans, Grant Hupp, Stephanie Inabnet, Kelsey Martin, Andrew Pyle, Landry Shipman, Haley Spencer, Elizabeth Valerie, Sean Wilson and Jo Goy. Harding University

BiP-21. VEGETATION DIVERSITY IN NATURAL AND RESTORED FORESTED WETLAND SITES IN SOUTHEAST ARKANSAS
Chris Sheldon; Robert L. Ficklin; Karen Fawley
University of Arkansas at Monticello

BiP-22. USING ENVIRONMENTAL AND NATURAL HISTORY TRAITS TO PREDICT ON-GOING GLOBAL AMPHIBIAN DIE-OFFS
Kristina Frogoso[1]; Scott Connelly[2]
University of Arkansas at Little Rock[1]; University of Georgia[2]

BiP-23. DOES PELLET FEEDING AFFECT GROWTH AND DIGESTIVE PHYSIOLOGY IN JUVENILE CHANNEL CATFISH?
Cullen M. Shaffer; Jesse E. Filbrun. Southern Arkansas University

BiP-24. CONDITION OF LARVAL RED SNAPPER (*Lutjanus campechanus*) RELATIVE TO ENVIRONMENTAL VARIABILITY AND THE DEEPWATER HORIZON OIL SPILL
Jesse E. Filbrun[1,2], Frank J. Hernandez, Jr.[1], Jeff Fang[1,3], and John T. Ransom[1,4]
University of Southern Mississippi[1]; Southern Arkansas University[2]; University of Portland3; Benzie Conservation District, Michigan[4]

BiP-25. DISTRIBUTION AND ABUNDANCE OF INTRODUCED SEAL SALAMANDERS (*Desmognathus monticola*) IN NORTHWEST ARKANSAS, USA
Clint Bush. University of Arkansas

BiP-26. THE EFFECT OF CALCIUM APPLICATION ON REDUCING THE STRAIGHTHEAD OF RICE IN A FIELD WHERE STRAIGHTHEAD NATURALLY OCCURS
Meghnath Pokharel; Surendra Singh; Sixte Ntamatungiro; Bihu Huang.
University of Arkansas at Pine Bluff

BiP-27. EFFECTS OF TEMPERATURE DURING PANICLE DIFFERENTIATION WITH INTERACTION OF LIME APPLICATION ON RICE STRAIGHTHEAD AND SEED SET RATE
Surendra Singh; Meghnath Pokharel; Sixte Ntamatungiro; Bihu Huang
University of Arkansas at Pine Bluff

BiP-28. SIMPLIFYING GENE STACKING IN PLANTS USING SITE SPECIFIC RECOMBINASES AND NUCLEASES
Bhuvan Pathak; Jamie Underwood, Soumen Nandy; Shan Zhao;
Vibha Srivastava. University of Arkansas

BiP-29. LYCOTOXIN (I) FOUND IN THE VENOM AND DIGESTIVE FLUID OF THE WOLF SPIDER *Rabidosa rabida* (Areanae Lycosidae)
Sara Wilmsen; Dennis Province; Ryan Stork. Harding University

BiP-30. TRANSCRIPTIONAL REGULATION OF ROBO2 IN THE *Drosophila* EMBRYONIC NERVOUS SYSTEM
Gina Hauptman; Timothy Evans. University of Arkansas

BiP-31. FtsZ HOMOLOG FtsB ROLE IN *Dictyostelium discoideum* MITOCHONDRIAL DYNAMICS
Ericka Vogel; Kari Naylor; Pristine Pittman. University of Central Arkansas

BiP-32. *Dictyostelium discoideum*: RELATIONSHIP BETWEEN MITOCHONDRIA AND CYTOSKELETAL TRACTS DURING DIFFERENT CELL CYCLE STAGES
Kayln Holloway; Kari Naylor. University of Central Arkansas

BiP-33. EFFECT OF CHANGING LIGHT WAVELENGTH ON THE CULTIVATION OF *Selenastrum capricornutum*
James J. Malatesta; Jack Hunley. Ouachita Baptist University

BiP-34. PRECISION MEDICINE: A CASE FOR EXEMESTANE THERAPY
Bryana J. Gregory; Joshua D. Simpson; Nour M. Hussein
Harding University College of Pharmacy

BiP-35. EVALUATING EDUCATION AND OTHER INFLUENTIAL FACTORS ON THE PERCEPTIONS OF INFLUENZA VACCINATIONS
Shalynn Mills; Ben Rowley; Shawn Charlton
University of Central Arkansas

BiP-36. INVESTIGATING MOLECULAR MECHANISMS OF THYROID CANCER USING NOVEL CELLULAR MODELS
Anna Sharabura[1]; Ben Zamzow[1]; LeeAnn Jolly[2]; Aime Franco[2]; Laura MacDonald[1]
Hendrix College[1]; University of Arkansas for Medical Sciences[2]

BiP-37. INVESTIGATING CELLULAR MOTILITY IN THYROID CANCER USING NOVEL CELLULAR MODELS
Roshaneh Ali[1]; Will Gibson[1]; LeeAnn Jolly[2]; Aime Franco[2];
Laura MacDonald[1]
Hendrix College[1]; University of Arkansas for Medical Science[2]

BiP-38. ANALYSIS OF A RIBOSOMAL PROTEIN GENE IN TUMORS AND DEVELOPMENT
Seth St. John[1]; Deven Wray[1]; Helen Beneš[2]; Mary Stewart[1]
University of Arkansas at Monticello[1]; University of Arkansas for Medical Sciences[2]

BiP-39. PARKINSON’S DISEASE: A MITOCHONDRIAL-LIKED ETIOPATHOGENESIS
Stephanie Dayer; Avery Rasberry. University of Central Arkansas

BiP-40. THE TARGETED TREATMENT OF BREAST CANCER IN AFRICAN AMERICAN WOMEN
Toria Holland; Frank Hahn; Joseph De Soto. Philander Smith College

BiP-41. A NEW APPROACH IN TREATING PANCREATIC CANCER
Li Jiang; Frank Hahn; Joseph De Soto. Philander Smith College

BiP-42. NONI (*Morinda citrifolin*) MODULATES THE HYPOTHALAMIC EXPRESSION OF FEEDING-RELATED NEUROPEPTIDES AND HEAT SHOCK PROTEINS IN BROILERS EXPOSED TO ACUTE HEAT STRESS
Hossein Rajaei-Sharifabadi; Elizabeth Greene; Kentu Lassiter; Alissa Piekarski; Devin Cook; Kaley Blankenship; Phuong: Austin Decker; Lukas Gramlich; Yvonne Thaxton; Ken Hazen; Yi Liang; Laura Ellestad; Tom Porter; Walter Bottje; Sami Dridi
University of Arkansas

BiP-43. CHARACTERIZATION OF THE THIOREDOXIN SYSTEM IN *Methanosarcina acetivorans* REVEALS COMPLEXITY OF THE SYSTEM IN METHANOGENS
Addison C. McCarver; Faith H. Lessner; Daniel J. Lessner
University of Arkansas

BiP-44. METARHIZIUM ADHESINS AND ATTACHMENT
Susie Brown[1]; Kesha Pilot[1]; Stefan Jaronski[2]; Cynthia Fuller[1]
Henderson State University[1]; USDA ARS North Plains Research Laboratory[2]

BiP-45. PHYLOGENETICS AND MOLECULAR EVOLUTION OF LYMPHOCYTIC CHORIOMENINGITIS VIRUS
Morgan Howells; George Harper . Hendrix College

BiP-46. FATTY ACID METABOLISM CONTROLLED BY NHR-80 AND NHR-49 IS NECESSARY FOR *Caenorhabditis elegans* to SURVIVE IN SEVERE HYPOXIA
Quinton Anderson; Ben Saunders; Jo Goy. Harding University

BiP-47. IDENTIFICATION OF IMPORTANT RESIDUES IN *Arabidopsis* IBR3 USING SITE-DIRECTED MUTAGENESIS AND MUTANT PHENOTYPE COMPLEMENTATION ASSAYS
Amy Scott[1]; Rebekah Rampey[1]; Bethany Zolman[2]
Harding University[1]; University of Missouri- St. Louis[2]

BiP-48. IDENTIFICATION OF THE GENE DEFECTIVE IN J56, AN *Arabidopsis* AUXIN-CONJUGATE RESPONSE MUTANT
Ahmed Stivers[1]; Bethany Zolman[1]; Rebekah Rampey[2]
Harding University[1]; University of Missouri-St. Louis[2]

BiP-49. TRACKING DOWN THE SOURCE OF MICROBIOME IN STERILE ORGANS OF CHICKENS
Rabindra K. Mandal**; Tieshan Jiang; Robert F. Wideman Jr. University of Arkansas

BiP-50. CHARACTERIZATION OF AUXIN-INPUT PATHWAY COORDINATION TO MAINTAIN OPTIMAL AUXIN LEVELS IN *Arabidopsis*
Katrina Aardema; Tessa Henry; Bethany Zolman; Rebekah Rampey.
Harding University

BiP-51. THE EFFECTS OF HYPOBARIA AND INCREASED CARBON DIOXODE ON *Arabidopsis thaliana*
Jack Hunley; James J. Malatesta; Jim Taylor
Ouachita Baptist University

BiP-52. FIBER TYPE PROFILES OF NASAL MUSCULATURE IN THE BOTTLENOSE DOLPHIN (TURSIOPS TRUNCATUS)
Sarah McHugh[1]; Jennifer L. Dearolf[1]; Nicole M. Thometz[2]
Hendrix College[1]; University of California Santa Cruz[2]

CHEMISTRY POSTER PRESENTATIONS

CHP-1. TOTAL PHENOL CONTENT, ANTIOXIDANT ACTIVITY AND ANTIMICROBIAL ACTIVITY OF *CALLICARPA AMERICANA* PLANT EXTRACTS
Antoinette Y. Odendaal; Diana Mukweyi Southern Arkansas University

CHP-2. SEMIEMPIRICAL COMPUTATION OF Cu^{2+}–BOUND AMINO ACID COMPLEXES MODELED FOR HUNTINGTON'S DISEASE
Steven Adams; Cordell Wells; John Bentley; Peter Joseph; Joseph De Soto; Frank Hahn. Philander Smith College

CHP-3. GAS-PHASE AM1 QUANTUM CHEMICAL CALCULATIONS OF Fe^{3+}– BOUND AMINO ACID COMPLEXES MODELED FOR ALZHEIMER'S DISEASE
Steven Adams; Sabrina Hardy; Christopher Taylor; Alejandra Gutierrez; Joseph De Soto; Frank Hahn. Philander Smith College

CHP-4. THEORETICAL QUANTUM CHEMICAL CALCULATIONS OF Zn^{2+}– BOUND AMINO ACID COMPLEXES MODELED FOR PARKINSON'S DISEASE
Steven Adams; John Bentley; Cordell Wells; Joseph De Soto; Frank Hahn.
Philander Smith College

CHP-5. DETERMINATION OF FATTY ACID CONCENTRATIONS IN ALGAE
Donnell White; Beth Justice; Drake Palazzi.
University of Arkansas at Monticello

CHP-6. AN ATTEMPT TO ENHANCE THE CELL PROLIFERATION ACTIVITY OF THE HUMAN FIBROBLAST GROWTH FACTOR
Ellen Fields. University of Arkansas

CHP-7. PoPD-COATED OXYGEN SENSOR FOR In Vivo APPLICATIONS
Zayne Derden; Marlena Patrick; David Paul. University of Arkansas

CHP-8. RESPONSE OF GWALP23 PEPTIDES TO INCORPORATION OF SPECIFIC PAIRS OF BURIED CHARGED ARGININE RESIDUES
Karli A. Lipinski; Ashley N. Martfeld; Roger E. Koeppe II.
University of Arkansas

CHP-9. DETERMINING DIFFUSION COEFFICIENTS IN BULK SOLUTION AND THROUGH MEMBRANES USING ELECTROCHEMICAL TIME OF DIFFUSION (ETOD)
Madeline Meier; Jon Moldenhauer; David Paul. University of Arkansas

CHP-10. CONFORMATIONALLY-CONTROLLED LATE-STAGE MODIFICATION OF THE GLUCOSYL MOIETY TO FACILITATE SAR STUDIES OF IPOMOEASSIN
Lucas Whisenhunt; Wei Shi; Guanghui Zong . University of Arkansas

CHP-11. LACTOFERRICIN PEPTIDES: THE IMPORTANCE OF METHYL-TRYPTOPHAN AND GLUTAMINE FOR STRUCTURE AND ACTIVITY
Alexandrea H. Kim; Denise V. Greathouse. University of Arkansas

CHP12. ENGINEERING THE STRUCTURE OF FIBROBLAST GROWTH FACTOR THROUGH SITE DIRECTED MUTAGENESIS FOR INCREASED PROTEIN STABILITY
Julie Davis; Srinivas Jayanthi; T.K.S. Kumar. University of Arkansas

CHP-13. HELIX FRAYING MAY STABILIZE TRANSMEMBRANE ALPHA HELICES
Armin Mortazavi; Venkatesan Rajagopalan; Roger E. Koeppe II.
University of Arkansas

CHP-14. SYNTHESIS AND BIOLOGICAL EVALUATION OF AURONE-DERIVATIVES AS ANTI-TUBERCULOSIS AGENTS
Kevin Magana; Isaac Tamez-Salazar; Francis E. Umesiri.
John Brown University

CHP-15. UNIQUE PHARMACODYNAMIC PROPERTIES OF AB-PINACA; A NEW SYNTHETIC CANNABINOID FOUND IN K2/SPICE
Rachel Hutchison; Paul Prather; Benjamin Ford.

CHP-16. PHENOL CONTENT, ANTIOXIDANT, AND BIOACTIVITY OF *Smilax*
Lauren Morehead; Diana Mukweyi; Antoinette Odendaal.
Southern Arkansas University

CHP-17. DETERMINATION OF MINIMUM OXYGEN LEVELS REQUIRED FOR GLUCOSE LIMITED OXIDATION REACTION OF GLUCOSE VIA GLUCOSE OXIDASE ENZYME ELECTRODE
Hunter Jones. University of Arkansas

CHP-18. RADICAL SCAVENGING ACTIVITY, TOTAL PHENOLIC CONTENT, AND ANTIMICROBIAL ACTIVITY
Diana Mukweyi; Alyssa Bradford; Antoinette Odendaal.
Southern Arkansas University

CHP-19. PROGRESS IN SYNTHESIS OF POSSIBLE ANTI-MALARIALS
Casey Dodd; Martin J. Campbell. Henderson State University

CHP-20. BIOCHEMICAL INQUIRY INTO *CROTON CAPITATUS*, A NATIVE WEED
Mallory Bell; Martin J. Campbell. Henderson State University

CHP-21. CHEMINFORMATIC MODELING OF MUSCARINIC ACETYLCHOLINE RECEPTOR SUBTYPES 1-5 FOR THE TREATMENT OF NEURODEGENERATIVE DISORDERS
Henry North; Gaspar Melikyan. Harding University

CHP-22. ANALYSIS OF ELECTROLYTE CHANGES IN ATHLETES USING ICP
Casey O'Hara; George White; Jan Kiilsgaard; Ron Smith; and Gija Geme
Southern Arkansas University

CHP-23. ANALYSIS OF FLATHEAD CATFISH FOR MERCURY CONTENT IN LAKE COLUMBIA, ARKANSAS
Brishna Hedstrom; Gija Geme. Southern Arkansas University

COMPUTER SCIENCE POSTER PRESENTATIONS

CSP-1. PRIVACYCAMERA: COOPERATIVE PRIVACY-AWARE PHOTOGRAPHING WITH MOBILE PHONES
Ang Li[1]; Qinghua Li[1]; Wei Gao[2].
University of Arkansas[1]; University of Tennessee[2]

CSP-2. RULES FOR DIFFERENTIATING BETWEEN NON-ISOMORPHIC GRAPHLETS
John Calvin Alumbaugh*; Dale R. Thompson. University of Arkansas

CSP-3. IPv6 SECURITY PERFORMANCE ANALYSIS
Adrian Ordorica; Dale R. Thompson. University of Arkansas

CSP-4. THE EFFECTS OF DENIAL-OF-SERVICE ATTACKS ON SECURE TIME-CRITICAL COMMUNICATIONS IN THE SMART GRID
Fengli Zhang; Qinghua Li; Chase Ross. University of Arkansas

ENGINEERING POSTER PRESENTATIONS

ENP-1. MATERIAL AND OPTICAL STUDIES OF Si-BASED MID-INFRARED GeSn
Eleni-James Becton; Wei Du; Mansour Mortazavi.
University of Arkansas at Pine Bluff

ENP-2. NH_2-FUNCTIONALIZED MICROSILICA AND NANODIAMOND DIFFER IN TUNING GLASSY TRANSITION TEMPERATURES AND DIELECTRIC STRENGTHS OF THEIR EPOXY NANOCOMPOSITES
Huajun "Andrew" Zhou; Si Huang; Simon Ang. University of Arkansas

ENP-3. SiGeSn GROWTH FOR GROUP IV PHOTONICS
Perry C. Grant**;** Joshua M. Grant; Aboozar Mosleh; Wei Dou; Seyed Amir Ghetmiri; Hameed A. Naseem; Shui-Qing Yu.
University of Arkansas

ENP-4 OPTICAL TRACTOR BEAM AND MANIPULATION OF SMALL PARTICLES ON DIELECTRIC SURFACE
Nayan Kumar Paul; Brandon A. Kemp. Arkansas State University

ENP-5. GROWTH OF GePb & GeSn ALLOY FILMS USING THERMAL EVAPORATOR
Hakimah Alahmed[1]; Murtadha Alher[2]; Aboozar Mosleh[1]; Hameed A. Naseem[1]. University of Arkansas[1]; University of Karbala[2]

ENP-6. SYSTEMATIC STUDY OF Si-BASED Ge/Ge0.9Sn0.1/Ge PHOTODIODES WITH 2.6 µm DETECTOR CUTOFF
Thach Pham. University of Arkansas

ENP-7. OPTICAL PROPERTIES STUDY OF Ge1-xSnx ALLOYS BY SPECTROSCOPIC ELLIPSOMETRY
Huong Tran. University of Arkansas

ENP-8. PROPERTIES OF GaN/SiC HETEROSTRUCTURES FOR HARSH ENVIRONMENT POWER DEVICES
Stephanie Sandoval; Chen Li; Morgan Ware; Zhong Chen.
University of Arkansas

ENP-9. TEMPERATURE DEPENDENT STUDY OF GeSn LIGHT-EMITTING DIODES ON Si FOR MID-INFRARED APPLICATIONS
Yiyin Zhou. University of Arkansas

ENP-10. STABILITY OF CASCADED POWER CONVERTERS FOR MIGROGRID APPLICATION
Amlam Niragire; Roy A. McCann. University of Arkansas

ENP-11. INERTIAL FORCE-DRIVEN SYNTHESIS OF NEAR-INFRARED PLASMONIC NANOSPHERE COMPOSITES
Joseph Batta-Mpouma; George Sakhel; Arvind Sinha.
University of Arkansas

ENP12. TUDY OF LORENTZ FORCE ON A METALLIC MIE PARTICLES
Mohammad Habibur Rahaman; Brandon A. Kemp.
Arkansas State University

ENP-13. EFFECT OF EQUIVALENT HEIGHT, SURFACE AREA AND VOLUME OF THE DOME TO PRISM ON TORNADO FORCES USING CFD
Majdi Yousef; R. Panneer Selvam. University of Arkansas

ENP-14. INVENTORY SEGMENTATION PERFORMANCE IMPROVEMENT FOR MULTI-ECHELON REPAIRABLE ITEMS LOGISTICS SYSTEMS
Alireza Sheikh-Zadeh. University of Arkansas

ENP-15. OBTAINING HANDS-ON EXPERIENCE THROUGH BUILDING A CARTESIAN ROBOT FOR A MANUFACTURING CLASS PROJECT
Seth Loftin; Ricardo Romo; Mahbub Ahmed; Justin Vanhoose.
Southern Arkansas University

ENP-16. ARE 3D PRINTS FROM CARBON-FIBER REINFORCED FILAMENTS STRONGER THAN PLA AND ABS PRINTS?
Justin Vanhoose; Mahbub Ahmed; Md. Rashedul Islam.
Southern Arkansas University

GEOSCIENCE POSTER PRESENTATIONS

GSP-1. EXPLORING THE MECHANISM FOR IRON UPTAKE BY PHYTOPLANKTON: A BIOMARKER STUDY
Abigail Gatmaitan; Matthew Christie; Courtney D. Hatch.
Hendrix College

GSP-2. FLOODPLAIN SOILS—A POTENTIAL SOURCE OF PHOSPHORUS TO THE ILLINOIS RIVER
Megan Lord; Brian Haggard. University of Arkansas

GSP-3. WATER QUALITY EFFECTS ON PHYTOPLANKTON SPECIES AND DENSITY AND TROPHIC STATE INDICES AT BIG BASE AND LITTLE BASE LAKES, LITTLE ROCK AIR FORCE BASE, ARKANSAS, JUNE – AUGUST, 2015
Lucas J. Driver; Billy Justus. U.S. Geological Survey

PHYSICS POSTER PRESENTATIONS

PHP-1. NANOPARTICLE SIZE AND SHAPE CHARACTERIZATION WITH SOLID STATE NANOPORES
Santoshi Nandivada; Jiali Li; Mourad Benamara.
University of Arkansas

PHP-2. DETECT BINDING SITES AND EFFICIENCY OF BINDING OF RNAP HOLOENZYME ON λ DNA ATTACHED TO A PROBE TIP WITH SOLID STATE NANOPORES
Harpreet Kaur; Santoshi Nandivada; Mitu Chandra Acharjee; Changbae Hyun; Min Xiao; David McNabb; Jiali Li. University of Arkansas

PHP-3. NUMERICAL STUDY OF THE VARIATIONS IN THE DRIVING PRESSURE AND FREQUENCY ON THE MICROBUBBLES CONTRAST AGENTS AND ITS NONLINEAR BEHAVIOR
Aladdin Majeed Hasson, Abdul k. Hussein Dagher, Bassam T. Mohammad.
Al-Mustasiriyah University

PHP-4. OPTICAL CONSTANTS OF ALUMINUM DOPED ZINC OXIDE THIN FILMS
Sami Salman Chiad[1], Nadir Fadhil Habubi[1], Khalid Haneen Abass[2], Nidhal Nissan Jandow[1], Ismaeel A. Al-Baidhany[1], Wasmaa Abdulsattar Jabbar[1],Hassan Hadi Daroysh[1],Mohmood Muwafaq Abood[1]
Al Mustansiriyah University, Baghdad, (IRAQ)[1] University of Babylon (Iraq)[2]

PHP-5. GENERATION OF INCE-GAUSS BEAM LASERS
Allison Hine; Jessica Conry Young. Arkansas Tech University

PHP-6. SCANNING SYSTEM FOR MEASURING ACOUSTIC WAVEFIELDS
Clinton Costello*; Carl Frederickson. University of Central Arkansas

PHP-7. MEASURING NONLINEAR PARAMETERS OF GRAPHENE MATERIALS USING Z-SCAN TECHNIQUE
Thekrayat Alabdulaal; Gregory Salamo. University of Arkansas

PHP-8. SILICON MICRO-CANTILEVERS FOR PHOTOACOUSTIC SPECTROSCOPY SYSTEMS
Aiping Li[1]; Simon. S. Ang[2]; Marzia Zaman[2]; Xunli Zhang[1]; Haikuo Gao[1] Jun Chang[3]; Yongning Liu[3]
Binzhou University[1]; University of Arkansas[2]; Shandong University[3]

PHP-9. SPECIAL QUASIRANDOM STRUCTURES FOR PEROVSKITE SOLID SOLUTIONS
Zhijun Jiang; Yousra Nahas; Laurent Bellaiche. University of Arkansas

PHP-10. THE PITCH ANGLE DISTRIBUTION FUNCTION OF LOCAL DISK GALAXIES AND ITS ROLE IN UNDERSTANDING GALACTIC STRUCTURE
Michael S. Fusco. University of Arkansas

PHP-11. THE BLACK HOLE MASS/PITCH ANGLE RELATION OF TYPE I AGN IN SPIRAL GALAXIES
Amanda Schilling; Logan Jones; Julia Kennefick
University of Arkansas

PHP-12. IN SEARCH OF NONLINEAR GRAVITATIONAL WAVE MEMORY
Aaron Johnson; Shasvath Kapadia; Daniel Kennefick.
University of Arkansas

PHP-13. A STUDY OF THE CORRELATION BETWEEN THE SPIRAL ARM PITCH ANGLE AND THE DARK MATTER HALO CONCENTRATION OF THE BARRED SPIRAL GALAXIES
Ismaeel A. Al-Baidhany; N. N. Jandow; N. F. Habubi; W. A. Jabbar; S. S. Chiad; H. H.Darwish; Z. A. Toma. Al-Mustasiriyah University

PHP-14. LOW MASS X-RAY BINARY AGE AND LUMINOSITY Relation
William Shattuck. University of Arkansas

PHP-15. SIMION MODEL OF AN ELECTROSTATIC POSITRON STORAGE RING
Nicole Nichiniello; Jared Gavin. University of Arkansas at Monticello

PHP-16. CHANGES IN ELASTICITY OF RAT BONES EXPOSED TO SIMULATED MICROGRAVITY AND RADIATION
Hayley Heacox[1]; Lawrence M. Benzmiller[1]; Rahul Mehta[1]; Max Dobretsov[2]; Parimal Chowdhury[2]
University of Central Arkansas[1]; University of Arkansas for Medical Sciences[2]

A New Technique to Improve the Operation of Prosthetic Limbs during Muscle Fatigue

H. Albunashee[1], G. Rasool[2], K. Iqbal[1], and G. White[1]

[1]*Departmant of System Engineering, University of Arkansas at Little Rock*
[2]*Sensory Motor Performance Program, Rehabilitation Institute of Chicago*

[1] Correspondence: hmalbunashee@ualr.edu

Running Title: Improved Technique for Operation of Prosthetic Limbs

Abstract

Prosthetic limbs hold a promise to renew the quality of life for the amputee. Neural commands are decoded via a classifier to generate control signals for the prosthetic devices. In the literature, many challenges and limitations have been identified that affect the prosthesis operation. One such drawback is muscle fatigue which degrades the surface electromyogram (sEMG) signals, and consequently, the performance of the deployed classification algorithm declines from 90% to 50% of average accuracy. We used a new technique using the Linear Discrimination Analysis (LDA) algorithm and the muscle synergy-based task discrimination (MSD) algorithm to improve the classification accuracy. In this technique, during muscles contraction/fatigue, we used the LDA algorithms in the beginning and the MSD algorithms later. The applied technique exhibited better movement classification performance during normal and muscle fatigue conditions. However, more work needs to be done to effectively solve the muscle fatigue problem in prosthesis design.

Introduction

Although many research studies have shown promising results in the performance of myoelectric-controlled prosthesis, there is still a gap between that academic success and the real need of the amputee population in terms of the prosthesis reliability (Jiang et al. 2012). An internet survey that continued for four years revealed that many amputees were dissatisfied with mmyoelectric prosthesis functionality (Pylatiuk, et al. 2007). A similar study that reviewed 55 subjects with upper limb impairment found that they wore their prosthesis only for an average of 7.9 hours/day (Gaine et al. 1997). In addition, the study stated that most of the amputees with myoelectric-controlled prosthesis were not satisfied due to the poor performance of their prosthesis (Gaine et al. 1997). All these complaints towards the prosthetic limbs lead us to a discussion about challenges/factors that cause such limitations in the operation of the myoelectric-controlled prosthesis.

In the literature, the following factors were stated that they impact the performance of the prosthesis:

1- Muscle fatigue (Jiang et al. 2012, Scheme and Englehart 2011).
2- Sweat or perspiration (Jiang et al. 2012).
3- The electrodes' movement (Jiang et al. 2012, Scheme and Englehart 2011).
4- Fit of the socket (Scheme and Englehart 2011).
5- Variation of muscles' force or contraction level (Scheme and Englehart 2011).
6- sEMG signal's transient change (Scheme and Englehart 2011).

The performance of myoelectric prosthesis is extremely affected by the behavior of the sEMG signal which represents the electrical activity of muscles. The sEMG signal can be changed adversely due to the produced efforts by muscles. When muscles fatigue, a significant change occurs in the features of the sEMG signals—both time and frequency domain features are changed. Accordingly, the change in the sEMG signals affects the performance of a used classification algorithm which is utilized for subsequent control of prosthesis [master thesis].

The myoelectric controlled prosthesis utilizes supervised machine learning algorithms—classification algorithms to make a decision about intended tasks or movements. These algorithms assume the training data (the data used by a classification algorithm as a reference to compare with a real-time data or the validation data) has a static statue which means they are not changed overtime. In the literature, under such assumption, the classification accuracy of these algorithms was reported greater than 90%. However, as mentioned earlier, these data can be changed due to muscle fatigue. Therefore, such assumption is no longer valid when muscles fatigue.

Problem Statement and Related Work

The most commonly algorithms mentioned in the literature, which are used for task discrimination, are linear discriminant analysis (LDA), support vector machine (SVM), multiplier perceptron (MLP), artificial neural network (ANN) and hidden Markov model (HMM) (Scheme and Englehart 2011, Ortiz-Catalan, Brånemark, and Håkansson 2013, Rasool et al. 2015, Reaz, et al. 2006). Moreover, two new classification algorithms based on a muscle synergy hypothesis were proposed and applied in real time to discriminate between tasks—one was used for classification tasks of upper limbs and the other was used for classification tasks of lower limbs (Rasool et al. 2015, Afzal et al. 2015). The main difference between them that the first one was used for lower limb task classification, and it uses Non-Negative Least Square (NNLS) approach for neuron estimation. However, the second one was used for upper limb tasks classification, and it uses Kalman filter for neuron estimation. All aforementioned algorithms showed very high performance. For upper limb task discrimination, the used algorithm is called muscle synergy-based task discrimination (MSD). The MSD algorithm has shown a very promising performance when compared to 3 pattern recognition algorithms (SVM, AND, LDA), and indeed it displayed the best performance (Rasool et al. 2015).

Although, in normal operations, most of the proposed supervised machine-learning algorithms work to a sufficient level of accuracy (>90%) to classify the intended tasks, the performance of these algorithms declines significantly in muscle fatigue (Albunashee et al. 2016). The reason behind this declination belongs to the fact that these algorithms were tested under normal operation that the sEMG signals stay unchanged over time.

In our previous work, the impact of muscle fatigue on the classification accuracy was quantified. The classification accuracy declined from (>90%) to an average of 50% during muscle fatigue (Albunashee et al. 2016). In this study, the performance of two algorithms (LDA and MSD) during normal and muscles fatigue was monitored. Then, in order to improve the overall classification accuracy, we used both algorithms (instead of using one) during different periods of time of muscle fatigue. LDA algorithm was used in the beginning and the MSD algorithms later.

Muscle Synergy Hypothesis

Performing an intended task by a human hand is an extremely complex process. In order to perform an intended task, there are 38 muscles and 22 joints in the human hand and thousands of embedded sensors facilitating the integration (Ziegler-Graham et al. 2008). No single movement can be performed based solely on one muscle or one specific neuron signal (Rasool et al. 2015). This leads us to a discussion of "*how the nervous system overcomes these complexities to produce movement effortlessly and efficiently*" (Tresch et al. 1999). In human hands, different muscles cooperate together to perform the intended tasks based on weighted coefficients (brain/nerve signals) and muscle synergies (Rasool et al. 2015, Bizzi and Cheung 2013, Bizzi et al. 2008, d'Avella and Bizzi 2005, Tresch 2005, Rasool et al. 2013). Muscle synergies have been hypothesized as constant building blocks which are weighted by an unlimited number of neuron command signals (activation coefficients) to recruit the muscles to perform certain tasks/movements (Bizzi and Cheung 2013, Bizzi et al. 2008, d'Avella and Bizzi 2005, Tresch 2005).

MSD Framework

The MSD algorithm is explained in details in the references (Rasool et al. 2013, 2015). In this section, a breif description for the main components of MSD is explained.

The mathematical model of muscle synergy framework is described as follows: Time-varying weighted coefficients (X (k)), neuron drive, is mapped to a particular task (Y (k)) through fixed components, muscle synergies (W) as in (2).

$$Y_{m*k} = W_{m*n} * X_{n*k} \qquad (2)$$

where m, n and k are numbers of muscles/sensors, neuron drive coefficients and sample time respectively. The description of the MSD algorithms is explained as follows:

During the training session, MSD uses muscle synergy (W) as the training dataset after extracting them from the root mean square (RMS) values of the surface electromyogram signal (sEMG).

W is extracted from the RMS values (y) of sEMG using a blind source separation algorithm (BSS) such as non-negative matrix factorization (MNF) algorithm or probabilistic independent component analysis (pICA).

In the end of training session, W(s) of all tasks are saved as training dataset for the MSD algorithm. MSD algorithm, as any classifier, is based on finding the similarity between the training dataset and the validation/testing dataset. Therefore, in real time, having a new sEMG signal (y) and j number of movement, MSD uses (j) of Kalman filters to estimate the neuron command signal (X) for each possible movement (j) based in (2).

Kalman filter uses the measured sEMG signals (y) as the system's observation and a random walk model as the state-space model (given in 3)

$$\begin{aligned} X_{k+1} &= X_k + n1_k \\ Y_k &= \mathrm{W}\, X_k + n2_k \end{aligned} \qquad (3)$$

where $n1_k$ and $n2_k$ are system and measurement noise respectively. The estimation of Kalman filter is subjected with a constrain—the neuron drive (x) must be non-negative which is inherited from physiological bounds (Rasool et al. 2013).

In the end, after j (X) are estimated using j Kalman filters for each sensor of sEMG signal, the algorithm will make a decision of which movement is the intended one, based on measuring the similarity between the new (y) and all (j) constructed (y) using (2).

Experiment Protocol

This work is approved by Institutional Review Board of the University of Arkansas at Little Rock. Five volunteers (age 35±5 years) participated in this study.

In the 1st session, the subjects performed normal tasks, single-degree-of-freedom, 1-DoF (hand open, hand close, wrist extension, wrist flexion, forearm pronation and forearm supination). Each task was performed for five seconds (secs), followed by another five secs of relaxation (four times). There was rest time between every two consecutive tasks. In the 2nd session, the subjects were asked to perform each task one time with maximum voluntary contraction (100% MVC) for five minutes. All the participants were allowed to interrupt this session when they felt uncomfortable during the five minutes of the experiment—the average time of the experiment was 2.5 minutes due to participant discomfort.

Electrodes and Hardware Configuration

Seven electrodes were placed on the forearm. The focus was on the extensor carpi ulnaris (ECU), extensor carpi radialis longus/brevis (ECRL/B), extensor digitorum communis (EDC), flexor carpi radialis (FCR) and flexor carpi ulnaris (FCU), pronator teres (PT), and supinator (SUP). We used Naraxon TeleMyo (DTS) to record the sEMG data with a sampling rate (fs) of 2000 sample/sec. BioPatRec software was used for data acquisitions (Ortiz-Catalan et al. 2013).

Preprocessing the sEMG signal

For the LDA algorithm, 4 features were extracted from the sEMG signal after segmenting the raw sEMG in the size of 250 milliseconds (ms). The features are the waveform length (WL), zero crossing (ZC), mean absolute value (MAV), and slope sign change (SSC) (Rasool et al. 2015, Ortiz-Catalan et al. 2013). Then the features were divided into training and testing parts for evaluation purpose. The same approach was followed for MSD algorithm using the RMS values of the sEMG to extract muscle synergies.

Improving the Classification Accuracy

During normal operation, we confirmed that the 2 algorithms introduced a promising performance (>90%). During muscle fatigue, we used the recorded data during the first 50 seconds of the 2nd session to update the LDA algorithm. For the MSD algorithm, we used the extracted synergies during the 40-50 secs. The performance of the 2 algorithms was monitored for 150 seconds during the second session. Each algorithm was performing better for a period of time during muscle fatigue, as will be explained in the next section.

Results

When the MSD and LDA algorithms were updated with the new training dataset, both algorithms performed very well as shown in Figure 1. LDA, in the beginning, showed very good performance but in the end, the classification accuracy started declining. On the other hand, MSD showed poor performance in the beginning but it started getting better with time progression.

The two algorithms were used simultaneously. LDA algorithm was used for classification during the first 60-70 secs because it performed better than MSD and gave an accuracy of greater than 90% as shown in Figure 2. After 60 seconds, the MSD was used and it showed better performance than the LDA (>90% except in the last 10 secs, it showed 87%) as illustrated in Figure 2.

Discussion

In the beginning, the classification accuracy of LDA was higher than MSD not only because the muscles were not fully fatigued but also because LDA

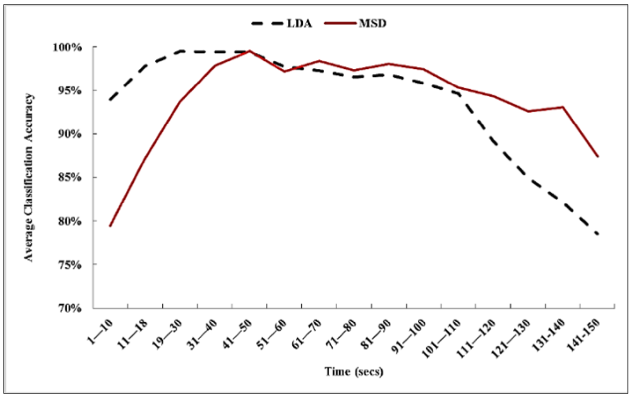

Figure 1. LDA and MSD algorithms during session 2

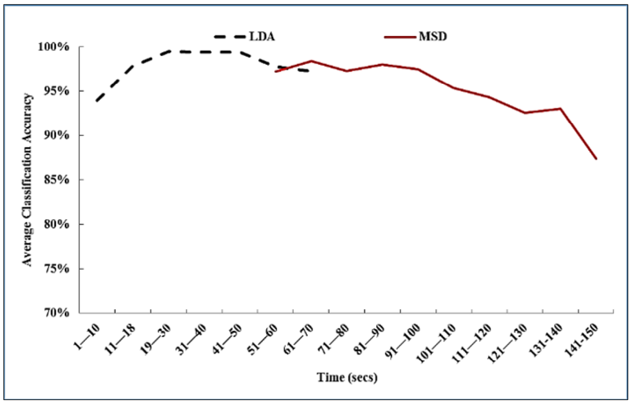

Figure 2. The performance of LDA during the first 60 secs and MSD during the rest of the 150 secs

uses more training features than MSD. On the other hand, when muscle fatigue, the performance of both algorithms declined (after 40 seconds). However, the declination in LDA was faster than in MSD, and for that reason, MSD was used instead of LDA. The fast declination in the LDA when muscle fully fatigued could be regarded to the fact that LDA is parametric classifier and MSD non-parametric classifier.

In order to apply the proposed technique in myoelectric-controlled prosthesis, the subjects (amputees) are required to perform an additional training session similar to the 2nd session (section 2). However, to avoid this issue, the training dataset which are used during muscle fatigue, should be generated from the training dataset which are collected during the 1st session.

Based on our investigation, we believe that using the MSD algorithm, *under same conditions*, is more applicable than the LDA algorithm because MSD requires updating only one feature instead of five features (in LDA case).

Conclusion

A new technique for task discrimination to control myoelectric controlled prosthesis was presented. In this technique, we used two supervised machine learning algorithms (LDA and MSD) to work during different times of muscle fatigue. In the first 60-70 seconds, we used LDA, and for the rest of the time, MSD was used. The overall performance of this technique was very good during muscle fatigue.

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Lithologic Character of the Paleozoic Sandstone Succession, Southern Ozark Region, Arkansas, and Missouri

E.C. Bello

Department of Geosciences, University of Arkansas, Fayetteville

Correspondence: ebello@uark.edu

Running Title: Paleozoic Sandstone Succession in Southern Ozark Region

Abstract

Sandstones comprise nearly half of the Paleozoic (Upper Cambrian-Middle Pennsylvania) lithostratigraphic succession in the southern Ozark region of northern Arkansas and southern Missouri. They record five distinct, but related intervals characterized by 1) Upper Cambrian arkoses resting unconformably on Precambrian granite; 2) Lower Ordovician reworked subarkoses, sublitharentites, and quartzites; 3) Lower Ordovician to Lower Mississippian reworked orthoquartzites; 4) Upper Mississippian first cycle sandstones with few metamorphic rock fragments (mrfs); 5) Lower Pennsylvanian (Morrowan) first cycle sandstones with common mrfs and Middle Pennsylvanian (Atokan) first cycle sandstones with common to abundant mrfs. These sandstones accumulated on a gently sloping cratonic platform reflecting transgressive-regressive, epeiric seas that eroded, transported, reworked and deposited more than 914.4m (3000ft) of terrigenous clastic sediments across what is now the south flank of the Ozark Dome.

Introduction

The Paleozoic record of the southern Ozark region, northern Arkansas, southern Missouri, and northeastern Oklahoma, accumulated on a gently sloping cratonic platform reflecting transgressive-regressive, epeiric seas that eroded, transported and reworked terrigenous clastic sediments (Zachry, 1979). The lithostratigraphic record recognizes at least 33 formations with a potential composite thickness of nearly 2438.4m (8000ft) (Howe and Koenig 1961, McFarland 2004, Fig. 1), although sea-level rise and fall produced regional surfaces of erosion; consequently, the preserved thickness is significantly less. Limestone and shale intervals dominate this composite thickness, but nearly 40% of the record is sandstone (Fig. 1).

Although there have been many excellent studies of the geologic history of the Arkoma Basin, the adjacent shelf, and Ozark Dome have never had a summary of similar comprehension. General papers on the southern Midcontinent, while useful, lack specific information applicable to the details of the geologic history and influence of the Ozark Dome on the region. Accurate analysis of the Arkoma basin fill, particularly the sandstones, has been limited because it is mostly in the subsurface. Perhaps oddly given its location, the Ozark Dome does not appear to have been a significant terrigenous clastic source for the surrounding region before the Mississippian. Its history has been apparently one of periodic uplift, and frequent cover, but there has been no recognition or evaluation of a tectonic signature preserved in the regional unconformities bounding the depositional sequences. The accepted regional geological history of the southern Midcontinent is interpreted as a cratonic platform through the Early Atokan Series with the actual formation of the Arkoma Basin beginning in the Middle Atokan.

Paleozoic Sandstone Succession, Southern Ozark Region

The Paleozoic sandstones represent five distinct, but related, intervals (Fig. 1): 1) the Upper Cambrian Lamotte Formation, an arkose, typically with a basal conglomerate, derived from the Precambrian granite of the Ozark Dome core; 2) sandstones of the Lower Ordovician Gasconade and Roubidoux Formations reflecting reworking of the Lamotte and contemporaneous intervals producing subarkoses, sublitharentites, and finally, quartzarenites; 3) continued reworking that produced well-rounded, well-sorted, orthoquartzites appearing in the Lower Ordovician Cotter Formation and extending to the Bachelor Sandstone, basal member of the St. Joe Formation, Lower Mississippian; 4) appearance of first cycle sandstones with a minimum of metamorphic rock

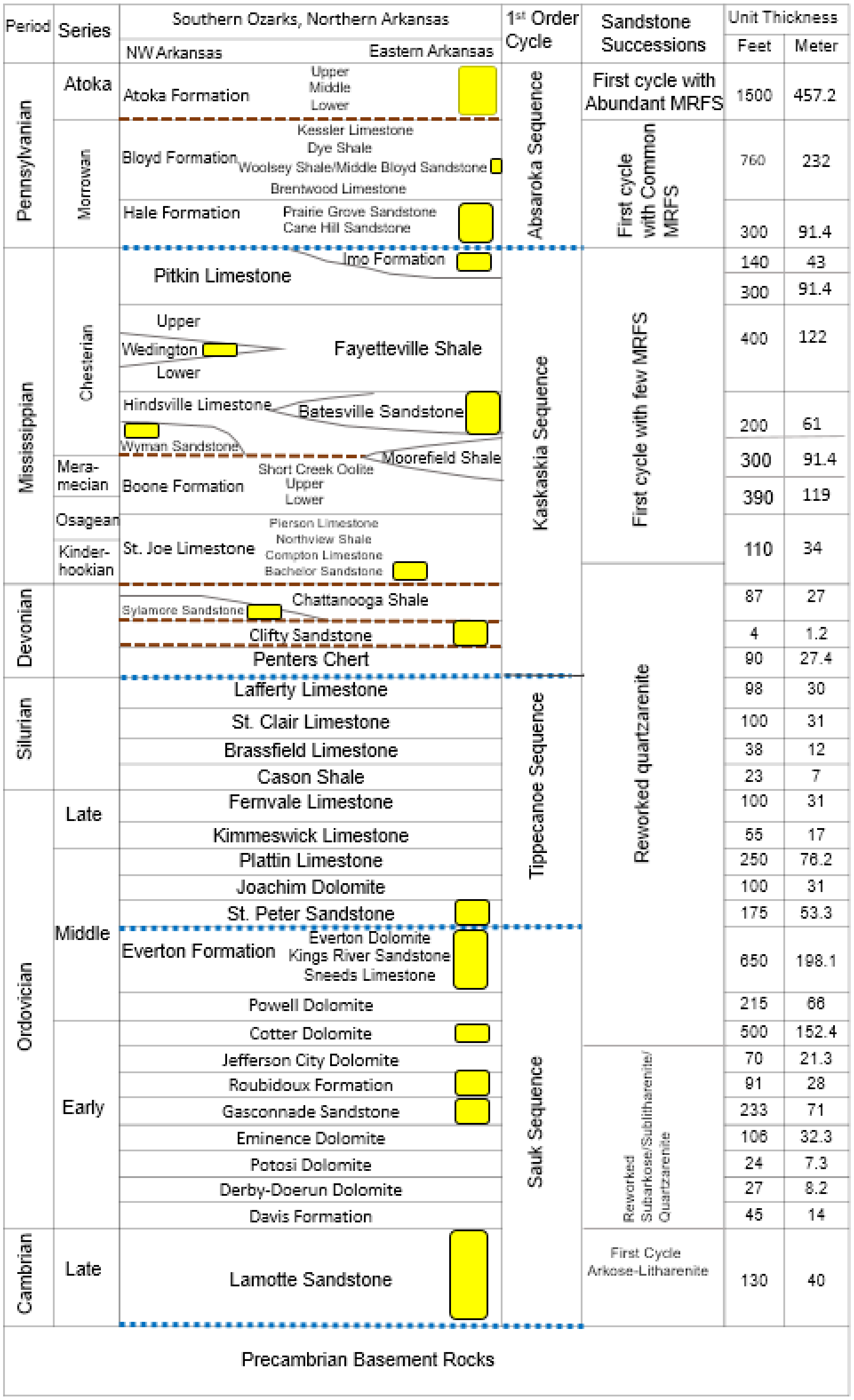

Fig. 1. Stratigraphic summary of Paleozoic northern Arkansas. Nomenclature, age assignments and average thickness compiled from and Howe and Koenig (1961), Haley and Frezon (1965), McFarland (2004) with some modification by the author. Total estimated thickness = 2033.3m (6671 ft); red and blue dotted lines represent craton-scale and local unconformities respectively. Yellow boxes denote formations that are entirely or partly sandstones.

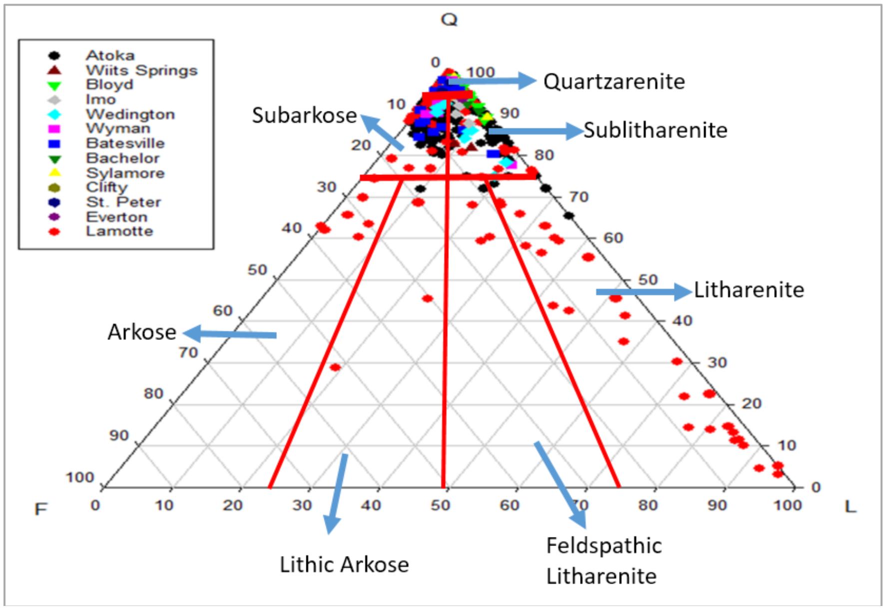

Fig. 2. Composite Plot of the Petrographic Analysis of the Paleozoic Sandstones of the Southern Ozark Region.

fragments (mrfs) beginning with the Upper Mississippian Batesville Sandstone Upper Mississippian, and appearing sporadically through the remainder of the Mississippian record to the base of the Pennsylvanian; 5) Pennsylvanian first cycle sandstones characterize the remainder of the record of the southern Ozarks, that can be subdivided into two categories: sandstones with common mrfs comprising the Morrowan interval, and sandstones with abundant mrfs capping the record as the Atoka Formation, Atokan Series, Middle Pennsylvanian, and the thickest Paleozoic unit in the southern Ozarks.

Petrographic Character of the Southern Ozark Sandstone Successions

Modal analyses plotted as ternary diagrams provide the evidence for the discrimination of the five groups of Paleozoic sandstones comprising the record of the southern Ozark Dome in Arkansas and Missouri (Fig. 2 and 3). As expected, the arkosic-litharenitic Lamotte Sandstone Interval 1 is distributed across the fields ranging from arkose to litharenite. The remainder of the sandstones is clustered in the sublitharenite-subarkose-quartzarenitic fields. All modal data have been separated and replotted on ternary diagrams for each of the sandstone intervals to further discriminate and characterize the five groups of Paleozoic sandstones identified in this study for the southern Ozark Dome in Arkansas and Missouri (Fig. 3).

Summary and Conclusions

Petrographic data for the Paleozoic sandstones of the southern Ozark Dome comprise five related, but distinct intervals: 1) first cycle arkose/litharenite, typically with a basal conglomerate, succeed by subarkose/ sublitharenite and finally to quartzarenite assigned to the Upper Cambrian Lamotte Formation; 2) after an interval of carbonate deposition, sandstones of the Lower Ordovician Gasconnade and Roubidoux Formations reflect continued reworking of the Lamotte interval producing subarkoses, sublitharenites, and finally quartzarenites; 3) well rounded, well sorted, quartzarenites and orthoquartzites that reflect reworking of the post-Lamotte quartz sandstones of the southern Ozarks and are represented by all or portions of the Lower Ordovician to Lower Mississippian Cotter-Everton-St.Peter-Clifty-Sylamore-Bachelor intervals. The Bachelor Sandstone, the basal member of the St. Joe Formation, Lower Mississippian, is the last orthoquartzite in the southern Ozark succession; 4) the Lower Mississippian Boone Formation, a chert-bearing limestone, is the thickest and most extensive post- Lower Ordovician and pre- middle Pennsylvanian interval in the southern Ozarks. This limestone interval limited significant reworking, and the Upper Mississippian records first cycle sandstones with few metamorphic rock fragments comprising the Batesville-Wyman-Wedington-Imo Sandstone interval; 5) first cycle sandstones with a major contribution by metamorphic rock fragments comprise

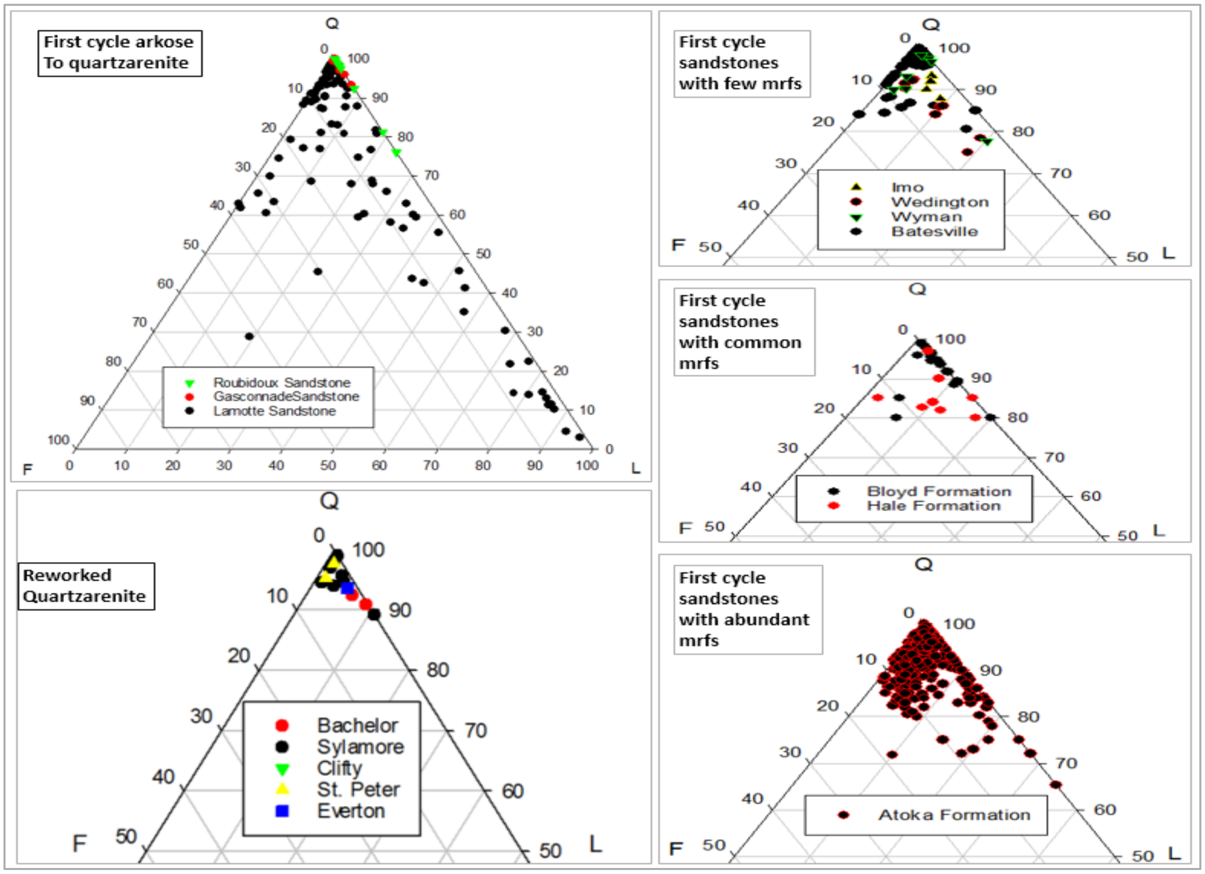

Fig. 3 - Plots of the Petrographic Analysis of the five Paleozoic Sandstone Groups Identified in the Southern Ozark Region. Thin sections provided by Angela Chandler and Richard Hutto, Arkansas Geological Survey; collections in Department of Geosciences, University of Arkansas, and data from Yesberger Jr. (1982) and Houseknecht (1975).

the Pennsylvanian portion of the succession. The Hale and succeeding Bloyd Formations, Morrowan, Lower Pennsylvanian, exhibit scattered to common metamorphic rock fragments, while the Atoka Formation, Middle Pennsylvanian, the thickest Paleozoic terrigenous clastic interval in the southern midcontinent unit and youngest stratigraphic unit in the Paleozoic succession of the southern Midcontinent preserves common to abundant metamorphic rock fragments

Acknowledgements

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Geochemical Processes and Controls Affecting Water Quality of the Karst Area of Big Creek near Mt. Judea, Arkansas

V. Brahana[1*], J. Nix[2], C. Kuyper[3], T. Turk[4], F. Usrey[5], S. Hodges[5], C. Bitting[6], K. Ficco[7], E. Pollock[8], R. Quick[9], B. Thompson[10], and J. Murdoch[11]

[1]*U.S. Geological Survey (Research Scientist Emeritus) and Department of Geosciences (Emeritus Professor), University of Arkansas, Fayetteville, AR 72701*
[2]*Department of Chemistry (Emeritus Distinguished Professor), Ouachita Baptist University, Arkadelphia, AR 71923*
[3]*Department of Chemistry Water Lab, Ouachita Baptist University, Arkadelphia, AR 71923*
[4]*National Oceanographic and Atmospheric Administration, Research Fisheries Biologist (Retired), Seattle, WA 98115*
[5]*National Park System, Buffalo National River, 402 N. Walnut, Suite 136. Harrison, AR 72601*
[6]*HC 73 Box 182 A,Marble Falls, AR 72648*
[7]*Department of Karstology, University of Nova Gorica, Slovenia*
[8] *Director, University of Arkansas Stable Isotope Lab, Fayetteville, AR 72701*
[9]*Woodward Clyde Consulting Group (retired); ADEQ (retired), Little Rock, AR 72118*
[10]*Tyson Foods, Inc. (Retired), Fayetteville, AR 72701*
[11]*Department of Biological and Agricultural Engineering (Retired), University of Arkansas, Fayetteville, AR 72701*

*Correspondence: brahana@uark.edu

Running Title: Geochemical Processes and Controls Affecting Water Quality of the Karst Area of Big Creek near Mt. Judea

Abstract

Karst regions typically are considered to be vulnerable with respect to various land-use activities, owing to the intimate association of surface and groundwater and lack of contaminant attenuation provided by most karst aquifers. Inasmuch as the soluble rocks of the karst landscape can be dissolved to create large, rapid-flow zones that compete successfully with surface streams, groundwater and subsurface flow represent a much larger component of the hydrologic budget in karst regions than in areas where non-soluble rocks predominate. Karst areas typically are distinguished by being unique, but some general approaches can be applied to characterize the hydrology of the area. These approaches include an evaluation of the degree of karstification, the hydrologic attributes of the groundwater flow system, the baseline water quality, the time-of-travel through the karst flow system, and the general flux moving through the system. The nature of potential contaminants and their total mass and range of concentrations are critical to understanding the potential environmental risk.

This study describes the characterization of the baseline water quality of the shallow karst Boone aquifer and surface streams and springs to determine major processes and controls affecting water quality in the region, and to assess 2 years of waste spreading. Parameters evaluated include major constituents, contaminants and their breakdown products from the industrial operation of a concentrated animal-feeding operation (CAFO) on Big Creek, the indicator pathogen, *E. coli*, dissolved oxygen, selected trace metals, and other ancillary water-quality attributes that are directly observable in the environment. Determination of pre-CAFO water quality was accomplished by sampling approximately 40 sites that included wells, springs, and streams.

Introduction

The recent (2012) Arkansas Department of Environmental Quality (ADEQ) issuance of a permit for a CAFO near Big Creek, slightly more than 10 kilometers (km) upstream from the Buffalo National River near the town of Mt. Judea, Arkansas (Figure 1), made Arkansas citizens aware of the potential for the CAFO to introduce solutes and pathogens that could degrade surface and groundwater in the area. The initial permit did not consider or discuss groundwater or karst, nor did it establish baseline water quality.

The waste generated from 6,503 hogs exceeds more than 7.5 million liters per year, and it must be continually removed to avoid overfilling the waste lagoons. Pig feces and urine spread on pasture land overlying karst has generated significant concern that the CAFO will create health problems for the many tourists who utilize the Buffalo, as well as many of the downstream landowners in Big Creek valley who use

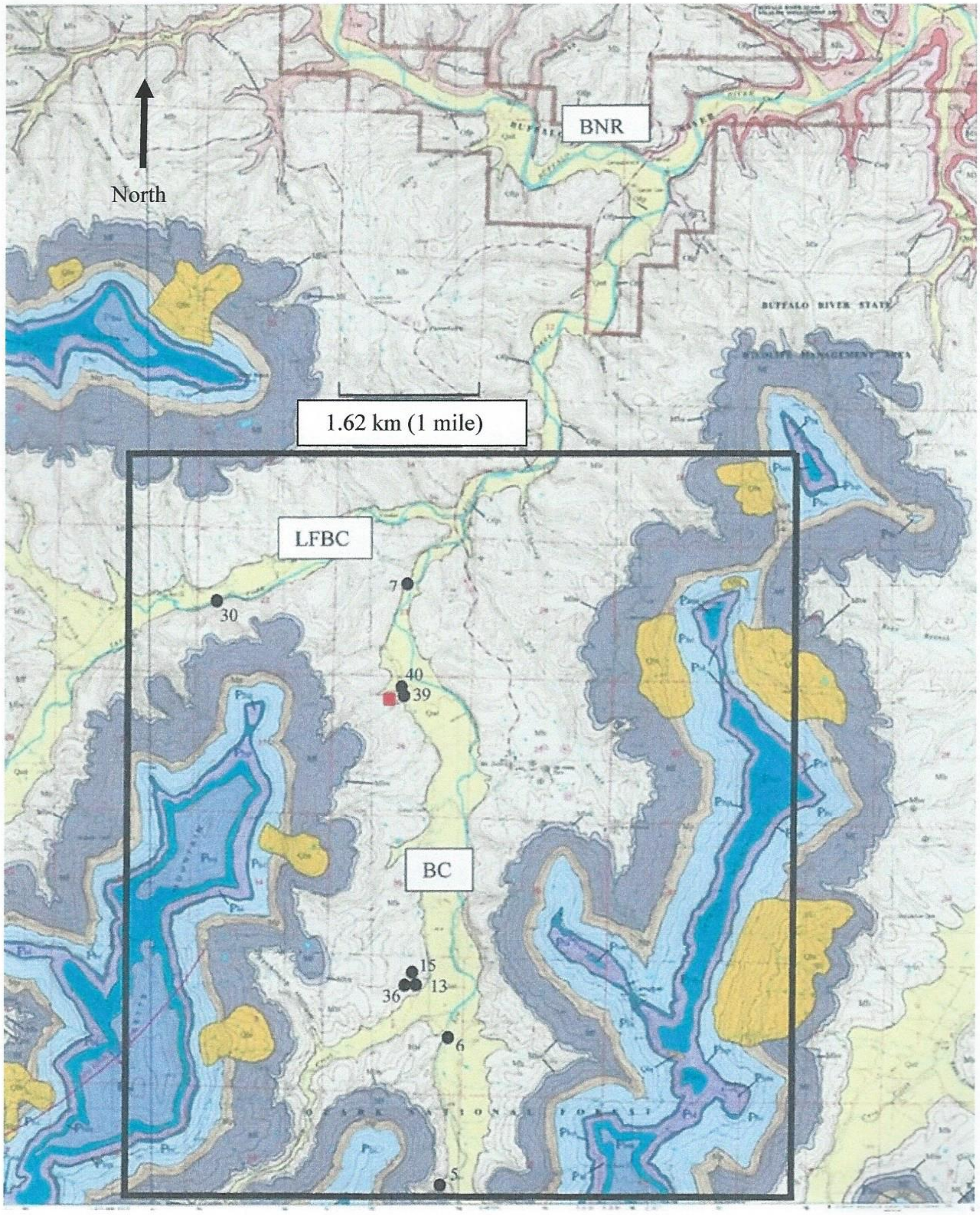

Figure 1. Geologic map of the study area, indicating the extent of karst where the Boone Formation (light grey color) occurs at land surface. BNR is Buffalo National River; BC is Big Creek and LFBC is Left Fork of Big Creek. The CAFO is shown by the red square, and the spreading fields for waste mostly lie between 7 & 6 on the west side of Big Creek. The study area is outlined by the black rectangle. Numbers 6 & 7 are referenced to Table 2. Numbers 5 & 30 are the furthest extent of groundwater tracing in the study area from dye input at 36, which has an altitude greater than any of the dye-receiving sites. The geologic base map is from Braden and Ausbrooks (2003). Topographic base map is from USGS (1980). Color legend for the map is in Figure 2.

the groundwater for domestic and stock water supplies. Canoeists and swimmers are particularly concerned because much of the drainage area of Big Creek has been karstified, which means that contaminated water with concentrated pig waste can move rapidly through open voids in the subsurface with little or no attenuation, and resurface in Big Creek, Left Fork Big Creek, or springs that drain the impacted area that lie downgradient. The main drain of this highly interactive groundwater/surface water system is the Buffalo National River (BNR on Figure 1). Insofar as the canoeists and swimmers cannot escape direct contact with river waters of the Buffalo (an Extraordinary Resource Water), citizen concerns seem warranted, and served as justification for conducting this study.

Physical Setting of the Study Area

Hydrologically, the study area includes the drainage basin of Big Creek including the waste-spreading fields of the CAFO, and the region surrounding site 30 on Left Fork of Big Creek (LFBC on Figure 1), which has been shown by dye tracing to receive groundwater flow beneath the topographic divide separating the two surface-drainage basins. The Boone Formation (from the base of the Batesville Formation to the bottom of the St. Joe Formation) is shown in Figures 1 and 2 as the light gray color in the central and northwest parts of the study area. The study area lies completely within Newton County.

The Boone Formation occurs across northern Arkansas in a broad outcrop band coincides with the Springfield Plateau physiographic province. This formation becomes karstified during weathering to facilitate groundwater capture of surface water, including the Mt. Judea area. Although this geologic unit encompasses about 35 percent of the land area of the northern two tiers of Arkansas counties, specific details of its hydrogeology are only generally documented in the literature. and its water-transmitting capacity and its ability to attenuate contamination has seldom been discussed other than to reference the entire area as a mantled karst (Aley 1988, Aley and Aley 1989, Imes and Emmett 1994, Adamski et al. 1995, Funkhouser et al. 1999, Braden and Ausbrooks 2003, Mott 2003, Hobza et al. 2005, Brahana et al. 2011, Kosič et al. 2015). Given this general cursory treatment, there exists a faulty claim that lack of obvious karst topography at air-photo scales is evidence that karst in the outcrop of the Boone Formation does not exist. The claim is inaccurate.

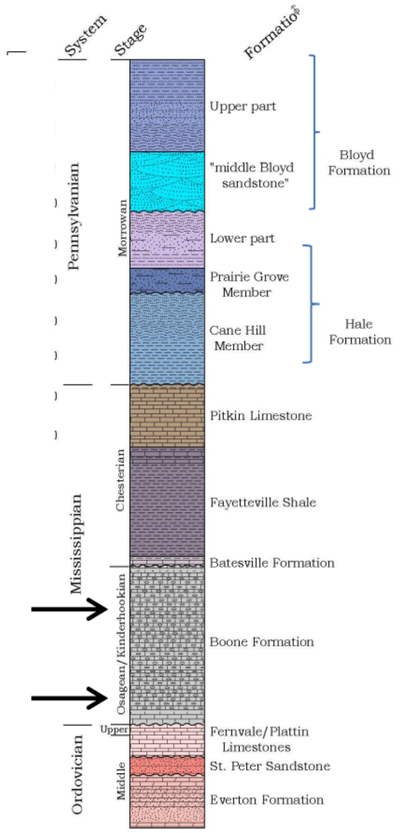

Figure 2. Stratigraphic column of the study area, showing the extent of karst where the Boone Formation (light grey color) occurs at land surface. Arrows identify the chert-rich interval of the formation. Total thickness of the Boone is about 110 m. Figure modified from Braden and Ausbrooks (2003).

The Boone Formation is a relatively thick unit, about 110 m with variable lithology, including limestone, chert, and minor thin shaley limestone layers. The soluble limestone of the Boone contrasts with the highly insoluble, brittle chert, which can occupy as much as 70 percent of the entire thickness of this formation. For the most part, the Boone contains no less than 50 percent chert, except in its upper and lower pure-limestone measures (Liner 1978). The Boone Formation is nearly flat-lying, and has numerous, thin interbedded limestone layers forming couplets with thin, areally continuous chert layers through much of its middle and lower sections of the formation (Hudson and Murray 2003). Brittle fracturing, a result of about 200 meters of total uplift in the distal, far-field of the Ouachita orogeny has allowed groundwater to chemically weather and karstify the formation (Liner 1978, Brahana et al. 2014).

The physical attributes of the chert at a regional scale appears to be near-uniform thickness, but in the field under close, non-magnified inspection, contact boundaries between the chert and limestone reflect thickening and thinning that one would expect in soft, non-indurated sediment, typically on the order of several centimeters. Whereas individual chert layers may possess similar thickness, different layers vary significantly, with some of the thicker chert units greater than 30 cm. The limestone lithologies in this interval range from less than 10 cm to several m.

The low permeability of the chert results in segregation and vertical isolation in this part of the groundwater flow system, which typically has been developed only in the limestone layers where the rock has been dissolved and karstified. The systematic orthogonal jointing resulting from the uplift and the long duration of weathering near the land surface are responsible for introduction of aggressive recharge and dissolution from the land surface to the hydrologically connected groundwater (Adamski et al. 1995, Davis et al. 2000, Funkhouser et al. 1999, Brahana et al. 2011).

Problem to Be Addressed

Significant land-use changes from a CAFO on karst required an accurate characterization of groundwater flow and the establishment of baseline water quality. Defining geochemical processes and controls was an essential first step in addressing these data gaps.

The CAFO is comprised of a 6,503-head facility for 2500 farrowing sows, 4000 piglets, and 3 boars; it was permitted to be constructed on the Boone Formation. In addition to the large structures housing the swine, two lagoons approximately one acre each were included as temporary holding facilities for urine, feces, and wash water from the operation. In addition, about 243 hectares of pasture land for waste were also approved on land underlain by the Boone Formation, or in the valleys with thin alluvial deposits directly overlying the Boone (Braden and Ausbrooks 2003). The waste generated from this CAFO is equivalent to the waste generated by a city of 17,000 people (Tietz, 2006).

In addition to the lack of characterization of 1) karst, 2) basic hydrogeology, and 3) a baseline assessment of water quality (Brahana and Hollyday 1988, Edmunds and Shand 2008), the risk of similar environmental and water-quality problems occurring on the Buffalo had been well-documented elsewhere (Quinlan 1989, Quinlan et al. 1991, Funkhouser et al. 1999, Varnell and Brahana 2003, Palmer 2007, Gurian-Sherman 2008, Brahana et al. 2014, Kocic et al. 2015). The waste generated from 6,503 hogs of this size exceeds more than 7.5 million liters per year, and it must be periodically removed to avoid overfilling the waste lagoons (Pesta 2012). Insofar as the swimmers, fishermen, and canoeists cannot escape primary contact with water in the Buffalo National River, which has been classified as an ERW, this research was undertaken as part of a sequence of karst hydrogeologic studies to fill in the missing scientific gaps that were not addressed in the original permitting and approval process.

Water samples from wells, springs, and streams in the study area were collected during the summer and fall of 2013 prior to waste spreading from the CAFO. Sampling was conducted in the field by teams of volunteers using approved U.S. Geological Survey methods (Wilde 2006). Prior to collecting each water sample, field parameters of temperature, specific conductance, and pH were measured and reported. Site location was determined using a Garmin Colorado global positioning system, with latitude and longitude recorded in degrees and decimal minutes, to four significant figures of decimal minutes.

Sampling and Sample Preservation

Grab samples were obtained at each of approximately 40 sites and shipped to the Ouachita Baptist University Water Lab. Samples were taken to accurately represent water-quality at the time of collection. Each sample was divided into 5 fractions, and appropriate preservation initiated for each subsample as indicated below.

Methods

Raw Unacidified {R_u] Sample: An untreated aliquot was placed in a 500 mL plastic bottle and placed on ice. This subsample was used for the lab determination of alkalinity, turbidity, and specific conductance.

Raw Acidified (sulfuric acid) [R_a] Sample: a sub-sample was placed in a 250 mL plastic bottle then acidified with sulfuric acid to pH 2 then placed on ice. This subsample was used for the determination of total phosphorus, total Kjeldahl nitrogen, and ammonia nitrogen.

Filtered Acidified [F_a] Sample: A 25- mL subsample was filtered through a 0.45 micron filter using a syringe and a plastic Swinex filter holder. The sub-sample was then acidified to pH 2 with nitric acid then placed on ice. This subsample was used for the determination of sodium, potassium, calcium, magnesium, iron, manganese, copper, and zinc.

Filtered Unacidified [F$_u$] Sample: A 25-mL subsample was filtered through a 0.45 micron filter then placed in a 25-mL plastic bottle then placed on ice. This fraction was used for the determination of nitrate nitrogen, chloride, and sulfate.

Microbial Sample: Microbial samples were collected in 125 mL sterile cups, with no filtration and no acidification ($_{raw}$). The sample was placed on ice, and transported to the analyzing laboratory (University of Arkansas Water Lab) within 8 hours from sampling.

Laboratory and Field Analyses

Major constituents and nutrients were analyzed by the Ouachita Baptist University Water Lab in Arkadelphia, Arkansas. Cations were analyzed with an inductively coupled plasma optical emission chromate-graphy (ICP-OEC), and anions were analyzed by high performance liquid chromatography (HPLQ). Pathogens were analyzed by the Arkansas Water Quality Lab (AWQL) on the campus of the University of Arkansas. This lab accommodated the short holding-time requirements. *E. coli* data reported in this paper were taken from the BCRET (2015) report, with analyses provided by AWQL using Idexx Quanti-tray equipment following Standard Methods in Water and Wastewater Analysis, method 89223-B. Stable isotopes of deuterium and oxygen-18 and dissolved selected trace constituents were analyzed by the University of Arkansas Stable Isotope Lab (UASIL) using Thermo Scientific iCAP Q inductively-coupled plasma mass spectrometer. Dissolved oxygen data were collected by the USGS using a dissolved oxygen logger that sampled every 15 minutes. The logger was deployed in Big Creek, and calibrated biweekly, following the procedure of Green and Usrey (2014).

Quality Assurance

Quality assurance, holding times, and sampling procedures employed in this study followed U.S. Geological Survey protocols (Wilde 2006). The Ouachita Baptist University Water Laboratory maintains an internal and an external quality assurance program, which includes periodic blind audits, checks for both precision and accuracy, and field blanks. The laboratory is certified by the ADEQ for each of the parameters reported. The minimum detection limits (MDL) for each parameter are given in Table 1.

Table 1. Chemical parameters analyzed by the Ouachita Baptist University Lab, and their minimum detection limits (MDL).

Parameter	MDL (in mg/L)
Major Anions	
Chloride	0.11
Sulfate	0.12
Alkalinity	1.08
Major Cations	
Sodium	0.06
Potassium	0.002
Calcium	0.079
Magnesium	0.006
Nutrients	
Ammonia Nitrogen	0.006
Nitrate Nitrogen	0.006
TKN	0.027
Total Phosphorus (low range)	0.008

Results and Discussion

Major Constituents

Water-quality data and synthesis from the major constituents indicate that the dominant processes controlling dissolved species in the water are dissolution, which is to be expected from precipitation recharging shallow aquifers, especially in karst regions. Mixing is also a predominant process, owing to the close interaction of surface and groundwater in karst settings, wherein recharge from surface precipitation events dilutes dissolved species in the groundwater. Background concentrations of dissolved chloride in groundwater were less than 5 mg/L, and concentrations of dissolved nitrate typically in the range of 1 mg/L or greater (Figure 3). Surface water samples typically had concentrations less than the mean for chloride, caused by dilution from upstream sources; nitrate experienced similar dilution, with reported concentrations not uncommonly between 0.1 to 0.5 mg/L (Figure 3).

Groundwater from the Boone Formation wells, springs, and surface water from Big Creek all are calcium- bicarbonate type (Figure 4). Deep wells beneath the cover of terrigenous sediments show the effect of less mixing, being more mineralized but still dominantly a calcium bicarbonate waters (Figure 4). Shallow wells and springs in the upper, overlying younger sediments (Figure 2) are indicative of less dissolution (Figure 3), with greater components of chloride and sulfate, typical of shales. Insofar as these are natural inorganic chemical solutes derived from dissolution and modified by mixing, and within EPA guidelines, none are considered to be hazardous to the overall health of water quality in Big Creek valley.

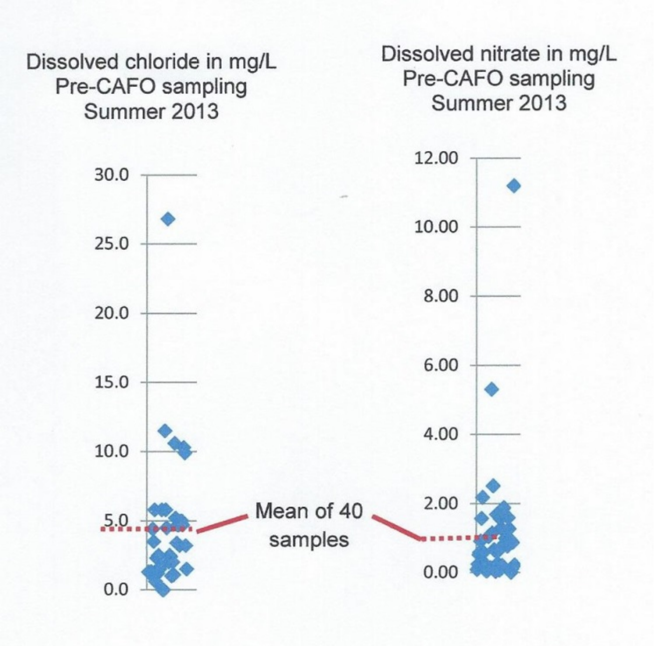

Figure 3. Concentration of dissolved chloride and nitrate sampled during the summer of 2013, prior to spreading of hog feces and urine on the spreading fields. The mean chloride concentration of 40 samples, which included groundwater from wells and springs and surface water from streams in the study area, was 4.5 mg/L. The mean nitrate concentration of 40 samples in the study area was 1.15 mg/L. Mean concentrations are shown by the dotted line. All units of concentration are mg/L

Microbes

Microbes are microscopic organisms that live in the guts of warm-blooded animals; they move into the environment upon defecation by the host, and they have the potential to be pathogenic to animals and humans when entrained in water and ingested. *E. coli* are an indicator organism of bacterial microbes. They are sampled to assess risk from primary contact with natural waters (Usrey 2013). In Big Creek, *E. coli* were sampled by the Big Creek Research and Extension Team (BCRET), as well as, the Karst Hydrogeology of the Buffalo National River (KHBNR) team. The Arkansas Pollution Control and Ecology Commission [APCEC] established criteria (APCEC 2015) for *E. coli* limits for impairment of surface waters in the state, and for those having a drainage basin greater than 26.24 km^2 (10 miles^2) it was 410 colonies per 100 milliliters (col/100 mL). This limit for *E. coli* requires "no exceedance of more than 25% of samples from no less than eight samples taken during the primary contact season or during the secondary contact season" (ADPCE 2015).

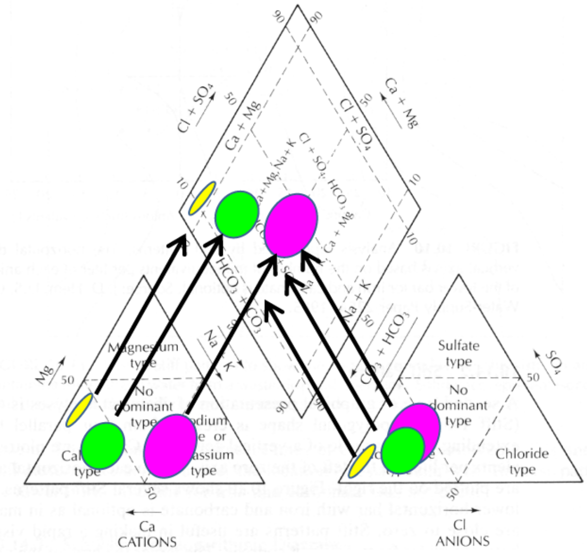

Figure 4. Piper diagram [modified from Hem (1993)] showing the general water-quality types in the exposed area of the Boone Formation (green), area of deeply buried Boone Formation with slow-flow karst attributes (yellow), and area of exposed, overlying, nonkarstified sandstone and shale aquifers (pink). These indicate that dissolution is the dominant geochemical process, coupled with mixing. This plot is based on pre-CAFO (2013) water samples. Figure 6 shows a cross-sectional view that identifies the general location of where these water types typically are found.

E. coli concentrations of single grab samples greater than 410 col/100 mL are not uncommon in streams, wells, and springs in the Big Creek drainage basin. For example, sites sampled during the summer of 2016 [6/14/2016 through 8/08/2016] (Figure 5) by KHBNR reflect extreme fluctuations that are attributed to multiple factors. These concentrations varied from less than 10 to 6,200 col/100 mL. Other examples included 6/24/14 *E.coli* concentrations in Big Creek which were 28,150 col/100 mL at site 6 , and 24,950 col/100 mL at site 7 (BCRET 2014).

Rapid changes in concentrations of microbes are a common expectation and have been observed in the Boone aquifer elsewhere (Marshall et al. 1999, Ting 2005), caused by mobilization of *E. coli* by resuspension in rapidly flowing surface and groundwater. Microbes have mass, and are deposited on the base of the flow systems when velocities slow during flow recession. Turbulence from rapid recharge

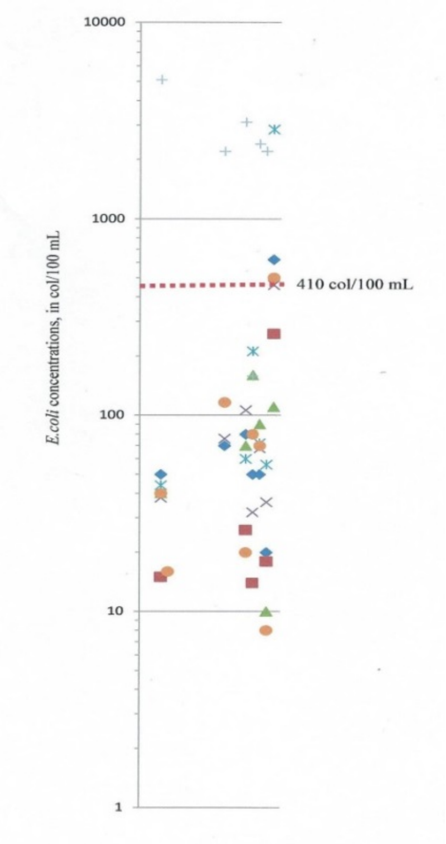

Figure 5. Semi-logarithmic plot of *E. coli* concentrations (in colonies/100 mL) for eight sampling intervals between 6/14/16 and 8/8/16. Samples were collected by the KHBNR team. Different patterns on the graph show different sampling periods. The red dashed line at 410 col/100 mL represents the *E. coli* concentration limit for Big Creek (non-extraordinary waters) the primary period. To be classed as impaired, a stream must be above this limit for five successive samples made during a 30-day period.

from storms resuspends the *E. coli* from the floor of the flow system, accounting for orders of magnitude increases. A key consideration here is that many of the *E.coli* persist in groundwater for periods of many months because of the lack of exposure of groundwater to ultraviolet rays, as well as to cooler groundwater temperatures. Although some die off of *E. coli* occurs in the subsurface, most organisms are entrained alive in the bottom sediment and have been shown to be viable for months (Whitsett 2001, Hamilton 2002). The dynamic nature and flow-path heterogeneity of karst flow ensures that each flow reach has a continuous and viable supply of these bacteria to share with downgradient receiving streams.

The similarity in timeframe and exceedingly high concentrations of *E. coli* at KHBNR sites is consistent with the connectivity of surface and groundwater in this watershed. Connectivity has been shown to directly impact the quality of downstream water in numerous other karst settings and locations (Winter et al. 1999, Palmer 2007).

Nutrients

Nutrients are compounds that are essential for plant and animal nutrition, and for this study the focus was primarily on nitrate. Animal feces are rich in nutrients, and too great an agricultural application rate can produce water-quality problems in receiving streams and groundwaters (Peterson et al. 2002, Sauer et al. 2008, Jarvie et al. 2014). Figure 7 shows a plotof nitrate concentrations versus time for two BCRET sites (BCRET 2016), 6 (upstream CAFO) and 7 (downstream CAFO) [Figure 1]. The dissolved nitrate concentrations from site 7 are greater than site 6 for the period of record, explained in part by the inflow of groundwater to Big Creek from springs which occur in the bed of the stream upgradient from site 7. Also notable are objectionable algal densities downgradient from these substream springs (Figure 8). Larger springs have been dye-traced from dye-injection well, site 36 (Figure 1) surrounded on 3 sides by spreading fields, and site 39 (Figure 1) across a county road and 200 m from the CAFO.

Summer 2013 analyses of nitrate in water in Big Creek valley (Figure 3) indicate that in some areas of the valley, the natural system had received more nutrients than could be adequately assimilated by crops, with dissolved concentrations of NO_3 as great as 11.3 mg/L analyzed from springs. Maximum EPA limits for nitrate are 10 mg/L, and although these elevated concentrations were present before the CAFO started, the groundwater system was obviously stressed during this time. In other locations in the valley where adequate dilution occurs, concentrations of dissolved nitrate typically are less than 1.0 mg/L.

Dissolved Oxygen

Dissolved oxygen (DO) concentrations in Big Creek were sampled by the U.S. Geological Survey at station 07055814 Big Creek at Carver. Automated probes sampled at 15-minute intervals, and were calibrated on a biweekly basis. Results from 2014 show a diurnal pattern of high concentrations during daylight hours, and low concentrations during the nighttime, which is typical. During daylight, algae in the creek generates oxygen, which is added to the water as it absorbs sunlight (due to photosynthesis). At night, oxygen is removed from the water, thus depleting DO from streams and rivers as part of a natural cycle. However, if measurements show the DO

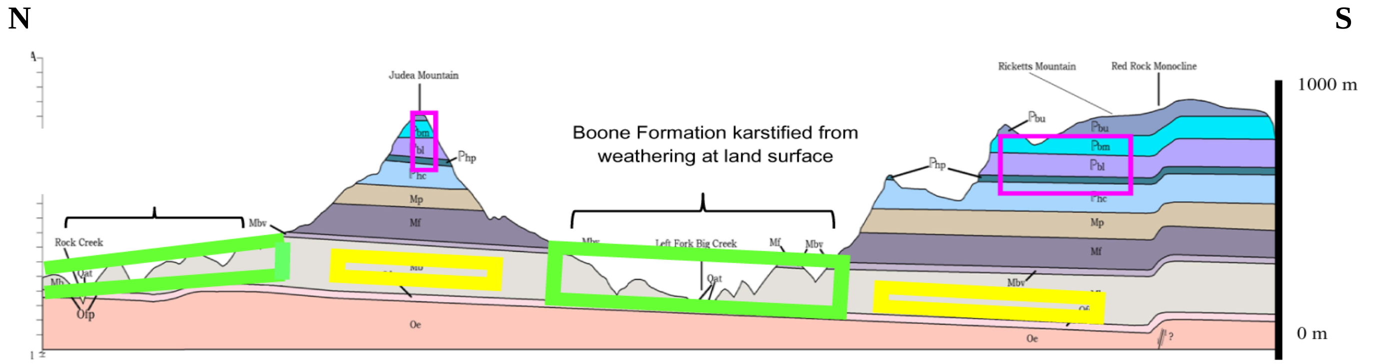

Figure 6. Generalized cross section showing typical water-quality types in the exposed area of the Boone Formation (green rectangles), area of deeply buried Boone Formation with slow-flow karst attributes (yellow rectangles), and area of exposed, overlying, nonkarstified sandstone and shale aquifers (pink rectangles). The line of section is along west edge of study area. Figure modified from Braden and Ausbrooks (2003).

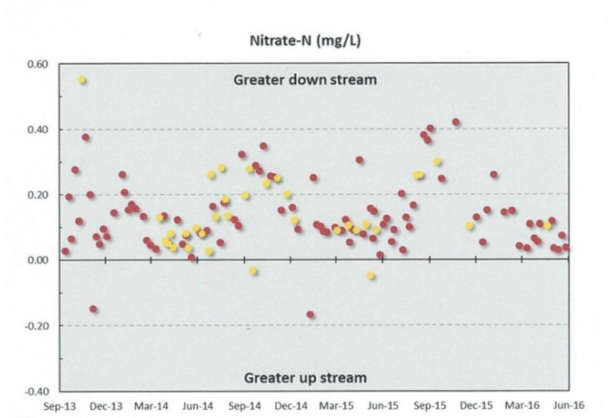

Figure 7. Plot of nitrate in mg/L verses sampling date showing the relation between upstream (Site 6-Figure 1) versus downstream BCRET sites (Site 7-Figure 1). Source of data and graph is BCRET (2016). Negative values for upstream site are necessary to plot the two stations together. Actual concentrations are positive.

Table 2. Periods of DO exceedence of Regulation 2 standards (APCEC 2015) during selected 8+ hour intervals in the summers of 2014 and 2015. Data are from U.S. Geological Survey (2016), site 07055814 Big Creek at Carver downstream from the study area.

Date	Start Time	Stop Time	Minimum Measured DO (mg/L)	Minimum DO Allowed (mg/L)
8/24/2014	2:45	11:00	4.4	5.0
8/25/2014	2:45	11:30	4.4	5.0
8/30/2014	3:15	12:00	4.5	5.0
9/1/2014	4:15	12:45	4.2	5.0
10/8/2014	5:45	15:15	5.8	6.0
8/10/2015	3:15	12:45	4.5	5.0

Figure 8. Objectionable algal densities on Left Fork of Big Creek downstream from an anomalously large spring (Brahana, 1997) at site 30 (Figure 1). Under high flow conditions, groundwater and dye were traced to site 30 beneath the topographic divide that separates Big Creek from Left Fork Big Creek.

concentration in the stream has dropped below the critical level, the stream is classified as impaired.

Minimum concentration of DO in this part of the Ozarks during the critical period is 5 mg/L for times when the water temperature is greater than 22^{o} C. Big Creek fell below 5.0 mg/L on multiple occasions during the summers of 2014 and 2015 (Table 2). Recently reported results from the National Park System conducting ongoing 15-minute DO monitoring of Big Creek during the summer of 2016 showed ongoing continuation of depressed DO.

As a comparison of DO on Big Creek to a nearby stream, DO concentration in the Little Buffalo River, slightly more than 10 km upstream from the confluence of Big Creek and the Buffalo River, was below 6 mg/L only 1 time for less than 3 hours total for the period measured during the sampling interval of summer 2013. The drainage basin of the Little Buffalo River has a similar distribution of land use and population as Big Creek, but it does not contain any CAFOs.

Trace Metals

Trace metals are dissolved cationic constituents that typically occur in water in very small concentrations (parts per billion or µg/L). Trace metals serve as effective tools for hydrogeologists to determine if groundwater contamination is occurring. If the trace metals can be connected with a specific land use, they may also serve as valuable indicators to suggest the potential contamination source. Relevant

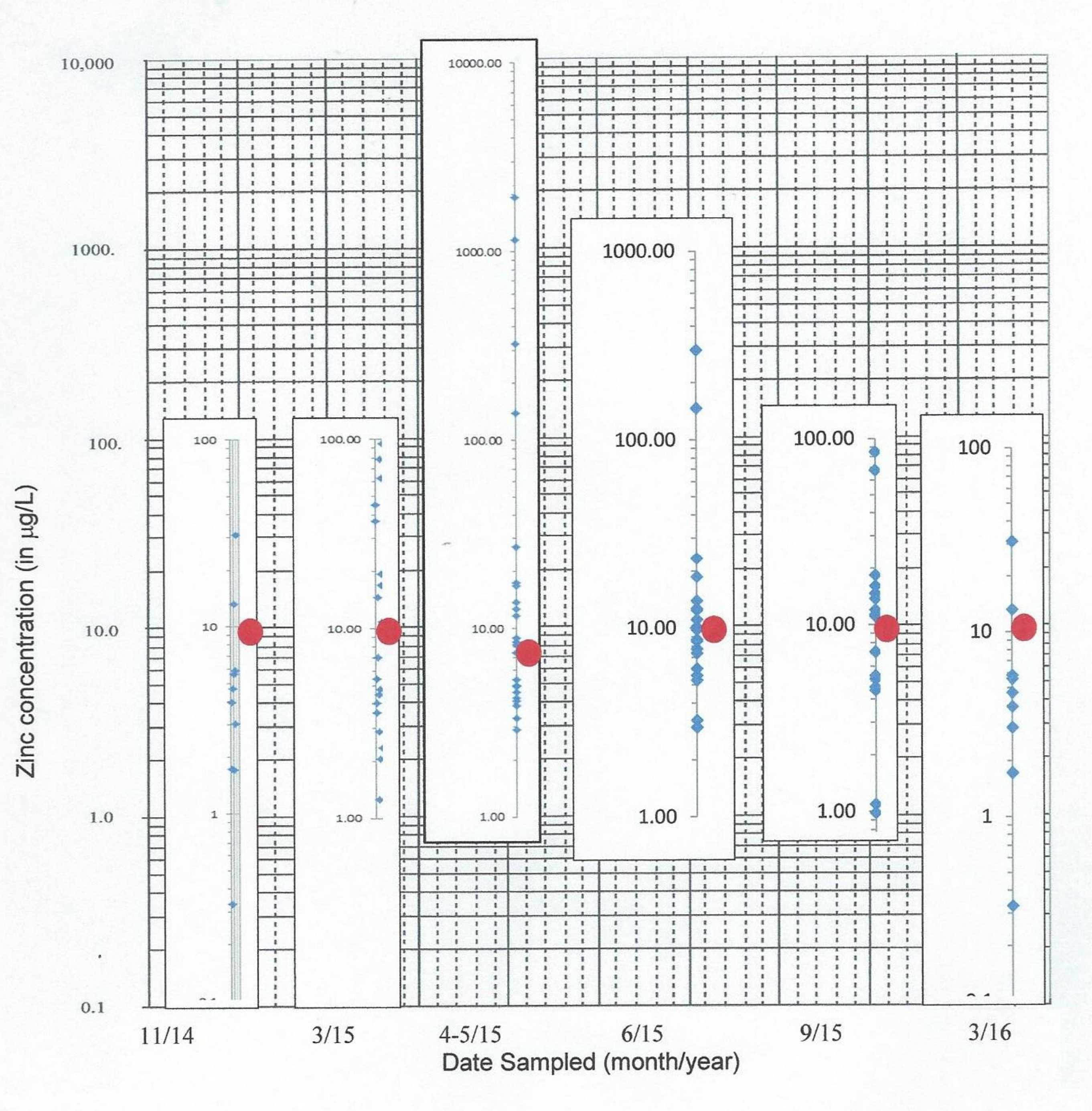

Figure 9. Dissolved zinc concentrations in groundwater and surface water in µg/L (ppb) plotted by date sampled, plotted on semi-logarithmic paper in blue diamonds. QA/QC values are shown by the red circles, and reflect the iCAP MS value for 10 µg/L standard for each suite of analysis by date. Precise sampling dates and hydrogeologic conditions during sampling are November 15, 2014 (low flow); March 17-18, 2015 (intermediate flow); April 13-May 11, 2015 (high flow); June 3-4, 2015 (high flow); September 8,2015 (intermediate flow); and March 7, 2016 (low flow).

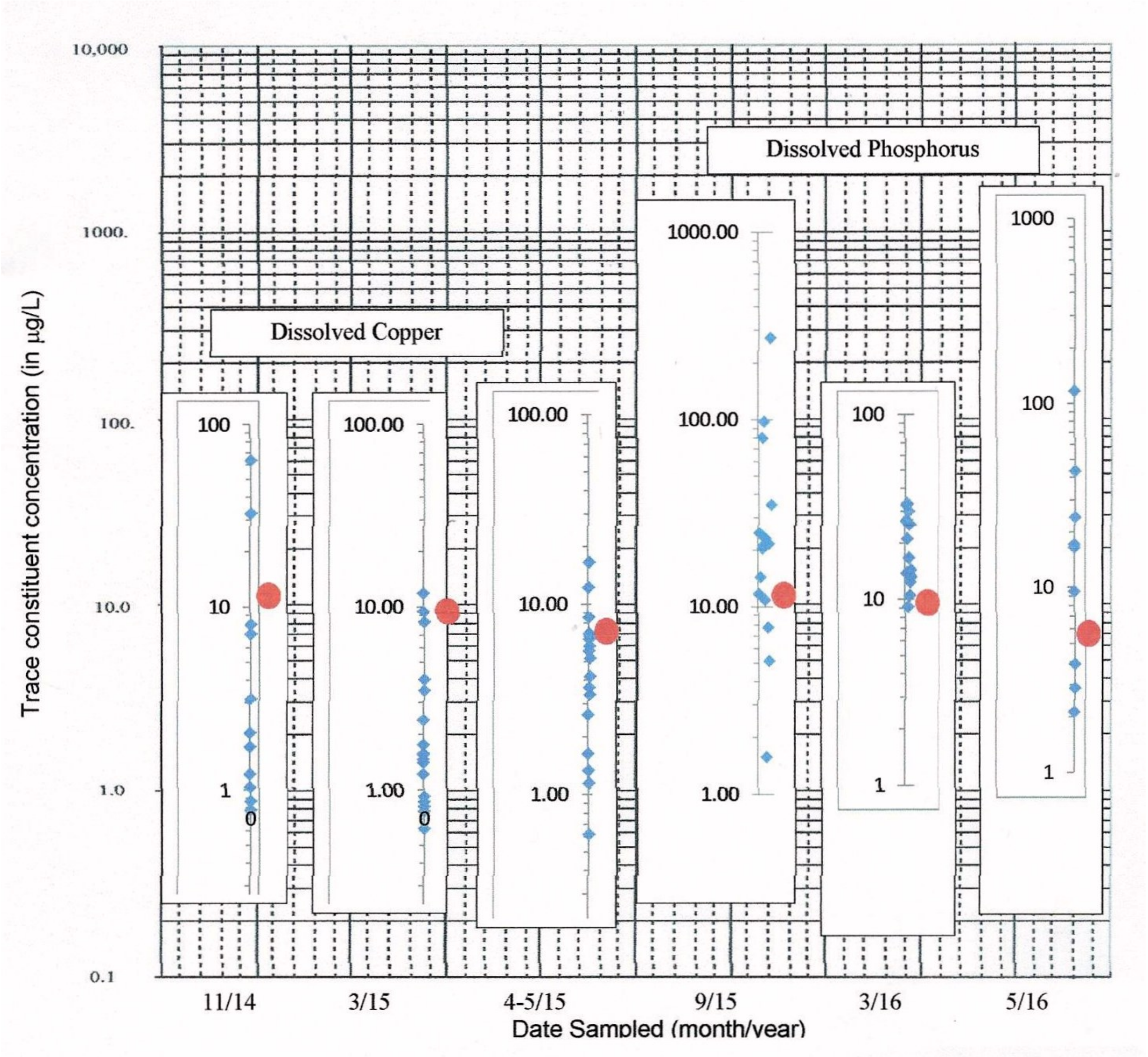

Figure 10. Dissolved copper and phosphorus concentrations in groundwater and surface water in µg/L (ppb) plotted by date sampled, plotted on semi-logarithmic paper in blue diamonds. QA/QC values are shown by the red dots, and reflect the iCAP MS value for 10 µg/L standard for each suite of analysis by date. Precise sampling dates and hydrogeologic conditions during sampling are November 15, 2014 (low flow); March 17-18, 2015 (intermediate flow); April 13-May 11, 2015 (high flow); September 8,2015 (intermediate flow); March 7, 2016 (low flow); and May 10, 2016 (intermediate flow).

to this study, two of these trace metals are reported to be additives to pig feed (Jacela et al. 2010), including zinc (Zn), and copper (Cu). Phosphorus (P), a non-metal was also included in this study because its isotope ^{31}P is an indicator constituent of animal feces. Selected Zn analyses are shown in Figure 9, and Cu and P are shown in Figure 10. Seven trace-constituent sampling campaigns were undertaken between November 15, 2014, and May 10, 2016.

Preliminary results of this part of the sampling program revealed that two specific regions of the study area had anomalously high concentrations of Zn, Cu, and P. These locations included sites 13, 15, and 36 (Figure 1), which are surrounded by spreading fields that lie immediately upgradient from these springs and well, and sites 39 and 40 (Figure 1), wells that are down-gradient and within 200 m of the CAFO infrastructure and its ponds. Concentrations of trace constituents in these two general areas typically varied from one to two orders of magnitude greater than samples from surface water.

Stable Isotopes

The stable isotope ratios, deuterium/protium

($^{2}H/^{1}H$) and oxygen -18/oxygen-16 ($^{18}O/^{16}O$) were analyzed for each of ten water samples collected during a single sampling interval on March 7, 2016. The results are shown in Figure 11, and may be synthesized as lying on the global meteoric water line. The $\delta^{18}O$ values in units of per mil ($^{o/oo}$; parts per thousand against standard mean ocean water) have been plotted against the $\delta\ ^{2}H$ values for each of the samples, and are shown superimposed on the global meteoric water line (Craig 1961, White 1988). This close relation of the data to the meteoric water line gives us confidence that the interpretation that the source of the water comes wholly from precipitation, and that no geochemical processes (evaporation, addition of deep thermal water) are acting on the water to shift the data above or below the line. The global meteoric water line can be defined by an equation:

$$\delta\ ^{2}H = 8.0 \times \delta\ ^{18}O + 10\ ^{o/oo}$$

(Craig 1961) that relates the average relationship between H and O isotope ratios in natural terrestrial waters, expressed as a worldwide average (Standard Mean Ocean Water).

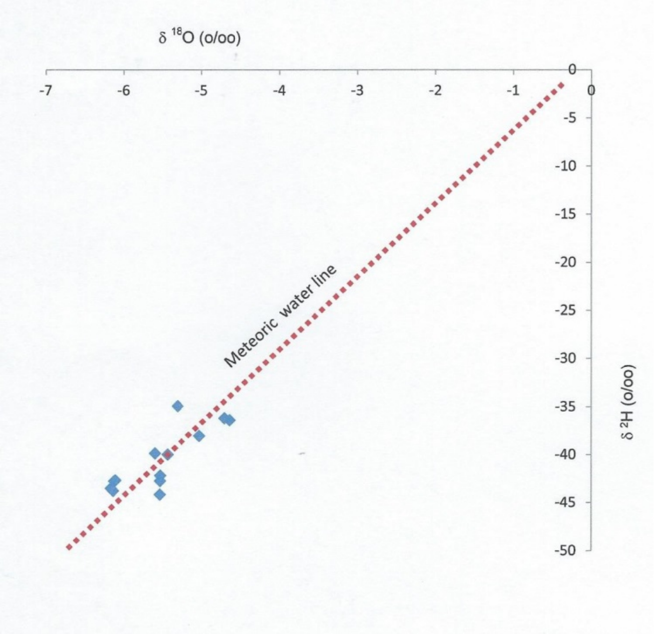

Figure 11. The stable isotopes of hydrogen and oxygen have been plotted for samples collected on March 7, 2016, and they lie on the meteoric water line. Data are shown as blue diamonds, and the meteoric water line is dashed, in red. Units of measurement are per mil (o/oo).

Ancillary Observation

Field observations of streams, springs and wells in Big Creek basin provide a good general overview of the general health of the integrated natural water system. During late-summer low-flow conditions when evapotranspiration is at its greatest, many of the tributaries and even the main stem of Big Creek cease to flow on land surface, a common occurrence on karst lands elsewhere. Water that has been trapped and pooled on the surface is evaporated, and commonly leaves a crust on the dry streambed (Figure 12). These reaches in the study area in the summer of 2013 smelled like a poultry CAFO, and the fields upgradient that supplied recharge to the creeks were reported (not verified) to have received poultry litter. The presence of the evaporative crust does establish the fact that solutes are present in the stream water.

Figure 12. During the summer of 2013, when precipitation declined and evapotranspiration increased, surface streams Big Creek and Left Fork of Big Creek displayed sections downstream from animal production fields that pooled, evaporated, and left a crust of dissolved minerals on the streambed. This evaporative crust was thicker, more odoriferous (strong poultry litter-like smell), and far more extensive than any personal observations of the coauthors had experienced during their careers in this region. It is shown here as white covering of the streambed.

Summary

Data from major constituents indicate that the dominant geochemical processes controlling water quality in Big Creek basin are dissolution and mixing with meteoric water, which is to be expected in a region underlain by karst. Groundwater in the Boone Formation from wells and springs, and surface water from Big Creek and its tributaries are a calcium-bicarbonate type, with various contributions from animal husbandry and other land-use activities on the land surface. Deep wells beneath the cover of terrigenous sediments show the effect of less mixing and dilution, being more mineralized but still dominantly calcium bicarbonate type (Figure 4). Shallow wells and springs in the overlying younger sediments are indicative of less mineralization, with greater concentrations of chloride and sulfate, typical of shales with interbedded sandstones.

Observations of objectionable algal densities and nuisance water-plant growth are indicative of excessive nutrients that have been added to the water from activities on the land surface. At this time, Big Creek basin does not typically experience water quality that exceeds acceptable EPA limits. However, numerous observations indicate that Big Creek basin has greater nitrate concentrations at its downstream sample site 7 (BCRET 2016). U.S. Geological Survey DO and BCRET and KHBNR *E. coli* data also document that Big Creek does qualify as an impaired stream during some summertime periods. Because Big Creek drains the fifth largest subbasin to the Buffalo, and animal husbandry is the dominant land use, we need to carefully manage the feces and urine we allow to leak into its flow paths.

All data suggest that it is important to incorporate karst and hydrogeology into our permitting process for CAFOs on soluble rock if we intend to preserve these environments and their contained water resources (Kosič et al. 2015). Groundwater is hidden from view, but it plays a dominant role in the hydrologic budget of karst. Considering the fact that the Buffalo National River is the main drain for all waters flowing from Big Creek, the many users of the river deserve a scientifically accurate assessment of the risks of primary contact with water for any number of intended uses. It is our opinion that water-quality in Big Creek valley is being degraded, and ongoing monitoring of both surface and groundwater is essential.

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Lower Mississippian Chert Development, Southern Midcontinent Region

J.M. Cains*, A. Potra, and E.D. Pollock

Department of Geosciences, University of Arkansas, Fayetteville, AR 72701

*Correspondence: jmcains@uark.edu

Running title: Lower Mississippian Chert Development, Southern Midcontinent Region

Abstract

The Lower Mississippian Boone Formation is a chert-bearing, fossiliferous limestone typically 100-115m. thick forming the Springfield Plateau across the tri-state region of northwestern Arkansas, southwestern Missouri, and northeastern Oklahoma. The Boone represents the maximum flooding, highstand, and regressive intervals of a single, third order transgressive-regressive carbonate cycle bounded by regional unconformities. Two types of chert occur in this formation, and provide the basis for subdivision of the Boone into informal lower and upper members in northern Arkansas. The lower Boone represents early Osagean maximum flooding conditions and consists of calcisiltites with interbedded dark, nodular chert. This chert exhibits compaction phenomena and shrinkage fractures, indicating a penecontemporaneous origin from reorganization of silica immediately below the sediment water interface prior to lithification of the carbonate sediments (Manger et al. 1988a). The upper Boone represents late Osagean highstand and regression and consists primarily of carbonate grainstones and packstones (Shelby 1986). This interval contains white, later diagenetic chert, interpreted as a groundwater phenomenon in which silica has replaced lithified carbonate along its bedding planes, replicating the fabric of the limestone (Manger and Shelby 2000). This later diagenetic chert replacement favors the finer grained intervals and replicates the fabric of the limestone being replaced.

Previous studies have shown that the penecontemporaneous chert typically comprises 40-50% of the lower Boone interval, while the later diagenetic chert contribution to the upper Boone ranges from 30-95% (Liner 1979). Understanding chert development is unsettled, and has been the subject of debate, primarily involving the source of the silica producing the chert, and the mode of formation of the chert-bearing intervals. Geochemical analyses suggest a volcanic rather than biogenic source for the silica in the Boone Formation.

Introduction

The Lower Mississippian Boone Formation is a succession of chert-bearing limestones deposited on a carbonate platform called the Burlington Shelf (Lane 1978). This succession in northern Arkansas reflects production of carbonates within effective wave base and subsequent transportation and deposition of excess sediment down ramp. There are two types of chert development in the Boone Formation that can be easily identified in outcrop and hand sample—penecontemporaneous and later diagenetic chert. Historically, Boone chert development has been attributed to a biogenic source (Hesse 1990). This study suggests that the primary silica source for the chert is more likely volcanogenic.

Geologic Setting

The geology of the southern midcontinent is dominated by the Ozark Dome, a broad, asymmetrical cratonic uplift (Manger et al. 1988b). A sedimentary section of Cambrian through Pennsylvanian units dips radially away from the Precambrian core (Manger et al. 1988b). Northeastern Oklahoma and northern Arkansas make up the south and west flanks of the dome, where beds are regionally dipping less than one degree (Chinn and Konig 1973). A series of major *en echelon* normal faults trends northeast-southwest, and are downthrown on the southeast (Manger et al. 1988b).

Three broad plateau surfaces are developed away from the center of the Ozark Dome, and include the Salem, Springfield, and Boston Mountains Plateaus. The Salem Plateau consists of Ordovician rocks, primarily limestones, dolomites, and orthoquartzitic sandstones exposed across much of southern Missouri and adjacent northern Arkansas. The Springfield Plateau comprises a thin and sporadic Silurian and Devonian section, succeeded by a thick, pervasive Lower Mississippian section at its top. The Boston Mountains Plateau includes Upper Mississippian through Middle Pennsylvanian strata (Manger et al. 1988b).

Lithostratigraphy

Differences in lithostratigraphic nomenclature exist within the tri-state area of northwestern Arkansas, northeastern Oklahoma, and southwestern Missouri. The term Boone is the oldest valid designation for the chert-bearing limestone in the southern midcontinent, the name being credited to J.C. Branner in 1891 for Boone County, Arkansas. Arkansas is the only state to formally use the name Boone, whereas the equivalent chert-bearing carbonate interval in Missouri is divided into three formations (ascending order): Reeds Spring, Elsey, and Burlington-Keokuk (Manger and Thompson 1982). In Oklahoma, this interval is designated the Reeds Spring and overlying Keokuk Formation (Huffman 1958). Recently proposed revisions in Oklahoma promote use of the names Reeds Spring and overlying Bentonville Formation, presumably separated by an unconformity (Mazzullo et al. 2013). The Boone Formation in northern Arkansas is subdivided informally into lower and upper members primarily based on chert content, but the transition from lower to upper Boone is also marked by a change to coarser-grained lithologies (Shelby 1986).

Fig. 1. Penecontemporaneous chert (dark blue-gray) within limestone (light gray) in the Boone Formation near Hindsville, Arkansas.

Penecontemporaneous chert in the lower Boone is dark, nodular, and poorly bedded. It disrupts the bedding of the limestone and exhibits compaction features and shrinkage fractures, indicating it was deposited prior to lithification of the limestone (Manger et al. 1988a). This type of chert is exclusive to the lower Boone, which represents the maximum flooding interval of a third order, eustatic cycle and consists of fine-grained calcisiltites (Shelby 1986). The chert is associated with deeper water settings during the maximum flooding interval, and understanding its formation involves understanding the transition of opaline silica to cryptocrystalline/ microcrystalline quartz. Through evidence recovered by the Deep Sea Drilling Project, it is known that silica experiences the following diagenetic maturation sequence: opal-A (A = amorphous) (siliceous ooze) → opal-CT (CT = cristobalite and tridymite) (porcelainite) → chalcedony (micro-fibrous quartz) → cryptocrystalline/ microcrystalline quartz (chert) (Kastner et al. 1977).

Fig. 2. Upper Boone later diagenetic chert (white) replacing crinozoan packstones/wackestones (dark gray) near Fayetteville, Arkansas.

Later diagenetic chert in the upper Boone interval is white to light-gray, fossiliferous, and follows limestone bedding planes (Fig. 2)(Manger et al. 1988a). This chert results from groundwater replacement of carbonate lithologies by silica, favoring the finer grained intervals due to greater surface area, and maintaining the fabric of the limestone (Manger et al. 1988a). Larger grains and bioclasts remain unaltered for the most part, with silicification fronts visible in thin section showing that replacement is incomplete (Manger et al. 1988a).

The idea of a volcanic silica source for chert is not a new one—it was cited by W. A. Tarr in 1926, among others. Goldstein (1959) stated that extrusive volcanism is the only sufficient source for the large amounts of silica present. Other previous explanations involve the remobilization of hard parts of siliceous micro-organisms, particularly sponge spicules (Hesse 1990), or aeolian deposition of siliceous sediments based on correlation between episodes of paleoaridity and chert occurrences (Cecil 2015). Tarr (1926) attributed silica in marine environments to input from continental weathering and transportation by rivers and streams.

Methods

A total of 40 chert samples were collected at 1.52 m. (five-foot) intervals from Boone roadcut exposures in Bella Vista, Arkansas; Pineville, Missouri; and Elkins, Arkansas. Chips were collected from samples and photographed under a Scanning Electron Microscope. Energy dispersive x-ray (EDX) was used to determine the surface elemental composition.

Seven samples were selected for trace element geochemical analyses. Each sample was cut into slabs, washed with deionized water, wrapped, and broken into pieces so that innermost, unaltered chips could be finely powdered using a shatter box. Samples were dissolved via a MARS 5 microwave digestions system from CEM Corporation using the sand digestion method utilizing HF, HCl, and HNO_3, under extremely high temperatures. A boric acid solution was used to neutralize the acids, and each was diluted by 10x. Finally, each sample was analyzed using the iCAP Quadrupole Inductively Coupled Plasma Mass Spectrometer (Q-ICP-MS).

Kelemen et al. (2004) published a comprehensive review of subduction-related magmatic arc geochemistry by compiling data from multiple sources. Included in these data are the specific trace element and rare earth element (REE) values associated with different arc types. Trace element and REE concentrations of the chert in the Boone Formation were compared to show whether there is a relationship between certain arc types and this chert. Trace element and REE data collected from the Q-ICP-MS were normalized to the compositional values of average primitive arc andesites for four different arc types: continental, intra-oceanic (Aleutian), boninites, and oceanic. Normalized values were plotted for each sample for each arc type on a log scale. Elements plotting near a value of one indicate similar concentrations.

Results and Discussion

Samples analyzed with EDX consistently showed the elevated presence of both aluminum and potassium in the chert, indicating possible volcanic input. Fig. 3 displays trace element concentrations normalized to average continental arc concentrations of the corresponding elements. For both continental arcs (Fig. 3) and intra-oceanic arcs (Fig. 4), ratios vary slightly, but ultimately plot near one, indicating volcanic input. The oceanic arc plot is not considered due to lack of comparable data points. The similarity of the concentrations of these elements within the Boone chert and volcanic arcs strongly suggests a relationship between the two. These data point to volcanism as a silica source for the chert.

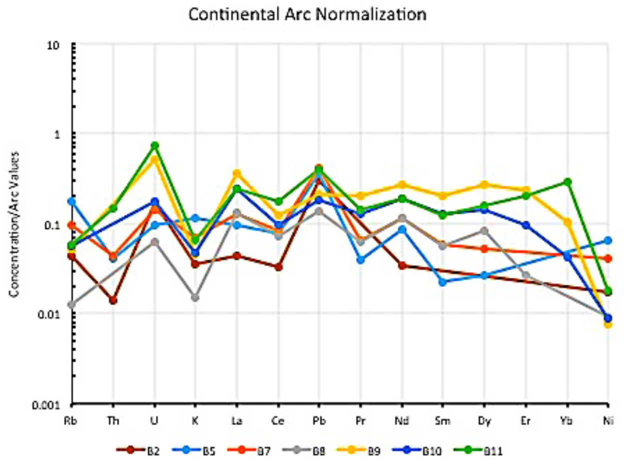

Fig. 3. Trace elements in Boone chert normalized to average continental arc values. B2, B5, and B7 are penecontemporaneous chert. B8, B9, B10, and B11 are diagenetic chert.

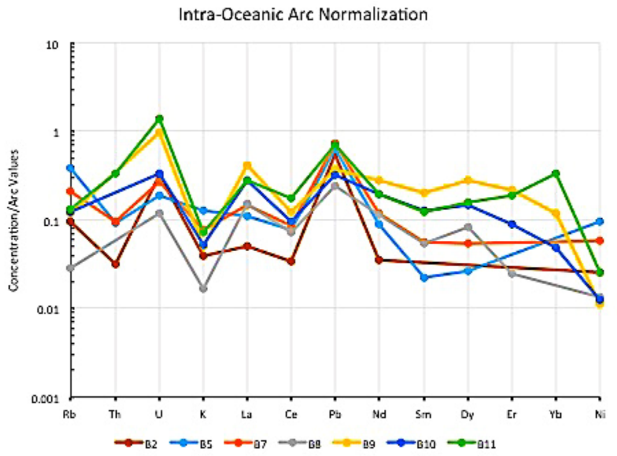

Fig. 4. Boone chert trace elements normalized to average intra-oceanic (Aleutian) arc composition.

Similar elemental compositions between the penecontemporaneous chert of the lower Boone and later diagenetic chert of the upper Boone indicate these two chert types likely share the same silica source. Penecontemporaneous chert likely formed from the mobilization and reprecipitation of silica derived from volcanic ash. This ash would have fallen through the water column and subsequently was reorganized to form amorphous silica below the sediment-water interface prior to carbonate lithification. Since the diagenetic chert is a replacement phenomenon, it is unlikely to have been derived from a biogenic source or direct silica precipitation. More likely this chert is a reflection of ash being dissolved and incorporated into groundwater, allowing replacement of the finer-grained carbonates by silica to occur.

Conclusions

Trace element concentrations clearly indicate that a subduction-related, extrusive volcanic source was involved in generating the chert in the Boone Formation (see also Philbrick et al., this volume). The ratios of trace elements between the chert samples and average arc values are highly comparable. Since the ratios plot near one for each arc type, there are not enough data to draw a conclusion on which specific arc type sourced the silica in the Boone Formation. The magmatic arc producing this ash likely formed from the collision of Laurasia and Gondwana that caused the Ouachita Orogeny. Increased volcanism associated with this orogeny would certainly be capable of producing the necessary amount of silica to account for the chert in the Boone Formation.

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Review

Plain Facts About Anthropogenic Global Climate Change and Warming: A Review

M.K. Cleaveland

Department of Geosciences, University of Arkansas, Fayetteville, AR 72701

Correspondence: mcleavel@uark.edu

Running title: Anthropogenic Global Climate Change

Abstract

Anthropogenic global climate change (AGC) is proceeding rapidly. The proximate cause is the greenhouse effect of carbon dioxide, methane and other greenhouse gases (GHG), which have rapidly accumulated in the atmosphere from burning fossil fuels and other human activities. Measurements of incoming and outgoing radiation have verified the warming imbalance. Effects manifest themselves in accelerating sea level rise and diminishment of the cryosphere. This has already created climatic refugees and water stress, and will destroy coastal infrastructure. It also impacts ecosystems and biodiversity in many ways. To avoid catastrophic effects, fossil fuel use must cease and carbon sinks must be protected and expanded. While voluminous scientific evidence supports the need for action, the U.S.A. has not acted. A survey of manifestos of geographically diverse conservative national parties in nine industrialized democracies (US, Canada, UK, Spain, Norway, Sweden, Germany, Australia, New Zealand; Båstrand 2015) shows that eight see this as an urgent problem to be solved; the exception being the U.S. Republican Party. I explore reasons for this anomaly.

Are Humans Changing Our Climate?

Major scientific societies certainly think that humans are changing the Earth's climate, e.g., the American Association for Advancement of Science (2013), which did a very thorough assessment of the problem that cited "overwhelming evidence" for AGC. Many other organizations, including the American Meteorological Society (2008), the American Geophysical Union (2012) and the Geological Society of London (2010) have affirmed their support for this position with similar statements. Many individual scientists have published their support for the idea, too, e.g., Flannery (2005), Doran and Zimmerman (2009) and Salinger (2005). Oreskes (2004) and Cook et al. (2013) surveyed publications on the subject and found a consensus that was especially strong among those doing climatology research.

Some excellent references on the subject include Hay (2016), a paleoclimatologist and geologist, and Houghton (2015), who has lead the Intergovernmental Panel on Climate Change (IPCC); both excellent summaries of our knowledge of this subject. There are many disciplines involved in this subject that also cover these issues. The latest IPCC findings (IPCC WG I 2013; IPCC WG II 2014a, 2014b; IPCC WG III 2014) offer a thorough explanation and evaluation of the physical basis of climate change, ongoing and possible future impacts and possible adaptation strategies. A good reference on atmospheric physics is Barry and Chorley (1998).

The Greenhouse Effect and Global Warming

Simply put, the atmosphere passes a considerable percentage of solar short wave (SW) radiation, which is absorbed by the Earth, and the planet then radiates the energy back into space as long wave (LW) radiation. Greenhouse gases (GHG) in the atmosphere, however, block some of the outgoing LW radiation, raising the Earth's temperature to reach equilibrium (Barry and Chorley 1998, Crowley and North 1991, Ledley et al. 1999, Leviticus et al. 2001, Ramanathan and Carmichael 2008, Ramanathan and Feng 2009, Raval and Ramanathan 1989). This effect is responsible for the Earth's temperature being higher than it would be if it had no atmosphere. CO_2 is a major GHG and atmospheric concentrations have paralleled global temperatures for at least 600 kyr (Houghton 2015, IPCC WG I 2013, Royer et al. 2004). In fact, CO_2 is the principal GHG, stabilizing Earth's climate (Lacis et al. 2010, Royer et al. 2004).

The Earth Radiation Budget Experiment (ERBE) and many other studies have measured the imbalance between SW and LW radiation leading to warming (Hansen et al. 2005, Huber and Knutti 2012, Ramanathan et al. 1989, Trenberth et al. 2009). Although uncertainties in measurements exist, there is no doubt more radiation comes in than leaves, creating ongoing warming of the planet. The global temperature records confirm this, showing a trend of increasing temperatures (with many excursions created by complexity of the system) since at least the late 19th century (NOAA 2016).

There is no doubt that CO_2, methane and other GHG concentrations have been rising since the industrial revolution began, that temperatures have also been rising and that much of the excess CO_2 comes from burning fossil fuels (Hay 2016, Houghton 2015, IPCC WG I 2013). The greenhouse effect has been understood since the 19th century and as early as the 1960s scientists understood that continued CO_2 buildup could have dire consequences (Weart 2015). Ignorant people have blamed volcanoes for the rise in atmospheric CO_2, but Gerlach (2011) has estimated that on an annual basis human sources emit 135 times as much CO_2 as volcanic activity. Solar activity does influence climate (Haigh 1996; e.g., the Little Ice Age, a period of low solar activity, Eddy 1976), but does not account for current global temperature trends (Duffy et al. 2009, Meehl et al. 2003, 2004).

Orbital variation governs the Earth's natural climate cycles of glacial periods interrupted by interglacials, the Milankovitch (1941) cycles (Hays et al. 1976, Weart 2015). At present we are in an interglacial period but we were transitioning into a glacial period as evidenced by over a thousand years of gradual cooling abruptly reversed by the industrial revolution increasing GHG concentrations (Kaufman et al. 2009). So our intervention has prevented a highly undesirable (from our point of view) glacial period. Our intervention, however, inadvertently creates a "hot house climate" that could damage human civilization as much or more than the glacial period we avoided. If we had the wisdom, we might have been able to prolong the present interglacial without melting the ice caps. The present orbital configuration creates cooling. If it were not for that, we would be warming even faster than we are now.

The year 2014 was the warmest since 1880 and 2015 was even warmer (NOAA 2016). Since little American effort has been made to eliminate emissions from fossil fuel utilization, in large part because of political and corporate obstruction (Bradley 2011; Mooney 2005, Oreskes and Conway 2010), it forces us to examine the evidence for climate change and the consequences of our inaction. Climate change is already underway and we have already begun to incur the consequences of our inaction, but much worse will occur in the future from the ongoing changes.

Table 1. Indicators of climate change due to human alteration of the atmosphere and the attendant environmental changes and the probability of changes greater than normal variability.

Indicator	Probability
Greenland ice loss	High
Antarctic ice loss	High
Loss of permanent Arctic sea ice	Very high
Loss of mountain glaciers	Very high
Decreasing snow cover	High
Ocean acidification	Certain
Longer fire season in U.S.	Very high
Animal migrations	Very high
Plant migrations	Very high
Changes in seasonal timing of plant and animal events (e.g., bud break, breeding, insect hatch)	Very high
Increased pest problems (e.g., bark beetles, invasive species)	Very high
Increased human conflict	Moderate
Refugees, esp. from low-lying islands	Certain
Drought, heat waves, floods	Moderate
Increased violent weather	?

Evidence Climate Change is Underway

Some of the most telling evidence for global warming comes from the cryosphere, sometimes called the air conditioner of the planet. The huge Greenland and Antarctic ice sheets hold a very large percentage of all the fresh water on Earth. The Greenland ice sheet loses more than 150 km^3/yr of ice (Dowdeswell 2006, Zwally et al. 2002), and the Antarctic ice sheet a similar amount (Velicogna 2009, Velicogna and Wahr 2006a, 2006b). Loss of the Greenland ice cap could raise sea levels by 7m and loss of the Antarctic ice more than 50m (Miller 2014). At present only the West Antarctic ice sheet is melting rapidly (Joughin et al. 2014), but the East Antarctic ice sheet may also be vulnerable (Cook et al. 2013a, Miller 2014). This, along with thermal expansion of the oceans as the planet warms, contributes to sea level rise. The loss of ice is accelerating, so it progresses nonlinearly (IPCC WG I 2013).

Scientists have consistently underestimated the rate of loss of Arctic sea ice (Johannessen et al. 1999, Levi 2000), which primarily affects the Greenland ice cap, and there is reason to believe that estimates of loss of ice from the ice caps may be greatly underestimated (Holland and Holland 2015). If that is the case, sea level rise in the near future could possibly be measured in meters, not centimeters. Sea level rise is an immediate threat along our coasts. Low lying cities such as Miami, Florida and Norfolk, Virginia are particularly vulnerable. Some neighborhoods in Norfolk flood every high tide (Kramer 2016).

Climate warming creates even greater climate warming through positive feedback. A good example of this is melting of Arctic ice that has a very high albedo, i.e., it reflects much of the sunlight falling on it back into space. Part of the enhanced melting occurs when the albedo is reduced by human atmospheric pollution, especially black carbon particulates emitted by power plants and diesel engines that fall on ice and snow, reduce the albedo, and increase melting of the snow and ice (Ramanathan and Carmichael 2008, Flanner 2009). Melting of high albedo ice and snow may expose much lower albedo water and tundra, which in turn increases absorption of solar radiation, leading to more warming and more melting.

In addition, various reservoirs of CO_2 storage may be destabilized, e.g., carbon stored in permafrost and frozen peat (Zimov et al. 2006) and methane hydrates on the seafloor, further accelerating global warming. The logical expectation would be that rising atmospheric CO_2 would lead to increased sequestration in terrestrial (e.g., forests) and marine sinks (e.g., coral reefs). This may not be the case, however, for example when increased CO_2 actually reduces carbon stored in soils (Heath et al. 2005). Other human actions, such as clearing of forests and destruction of coral reefs by pollution and warming water, also reduce the ability of sinks to respond to the overabundance of CO_2.

Of more immediate importance to humanity, most mountain glaciers are losing mass (Hall et al. 1992, Oerlemans 2005), and this exceeds past natural variability (Reichert and Bengtsson 2002). As an example, of an estimated mid-19th century 150 glaciers present in Glacier National Park, currently the park retains only 25, and they shrink every year (Pederson et al. 2004). This runoff from mountain glaciers changes seasonal distribution of water availability and it raises sea level, of course.

Additional evidence for climate change comes from minimum and maximum temperature trends. Minimum temperatures have increased more than maximum temperatures, reducing the diurnal range (Braganza et al. 2004, Easterling et al. 1997, Karl et al. 1993, Meehl et al. 2009). This is exactly what we would expect to happen if GHG are reducing LW radiation of energy into space.

Consequences

The IPCC (IPCC WG II 2014a, 2014b) and others (Hassol 2004, Strauss et al. 2016, Woodworth et al. 1992) have detailed the impacts of climate change. Sea level rise is already creating climate refugees as low lying islands experience flooding and salt water intrusion in their water supply. As an example close to home, some Florida mayors asked the Republican presidential candidates to address the issue of climate change (they refused) because the mayors recognize that Florida is extremely vulnerable to sea level rise. As ice cap melting accelerates, sea level rise is accelerating. If we do not stop the loss of glacial ice, and no one knows how to do that except by halting the rise of CO_2, eventually we will lose enormous amounts of coastal infrastructure. The cost of inaction has been quantified by Strauss et al. (2016). Coastal flooding will eventually displace millions, probably billions, of people (e.g., Rowley et al. 2007).

Rising atmospheric CO_2 levels create potentially disastrous changes in oceanic chemistry and ecosystems (Barnett et al. 2001, Caldiera and Wickett 2003, Feely et al. 2009). As CO_2 dissolves in sea water, it increases acidity and decreasing pH lowers the saturation state for carbonate minerals. This means that many marine species that form carbonate shells and skeletons, such as corals and foraminifera will be stressed or even destroyed (Zeebe et al. 2008). Such organisms form an important sink for CO_2 sequestration and their destruction or damage may be a positive feedback that increases atmospheric CO_2 levels.

The diminishing glacial runoff from mountain glaciers and snowpacks maintains streamflow and provides water for human and industrial consumption, irrigation and hydroelectricity in many regions, potentially affecting up to two billion people (Bradley et al. 2006, Hall et al. 1992, Mankin et al. 2015). Loss of the storage in mountain glaciers creates a strain on the societies that depend on them and may increase the number of climate refugees (Barnett et al. 2005). Recycling water might alleviate some of these stresses, but that requires technology and resources not universally available.

Heat waves have become a major factor in many places. A three-month European heat wave in 2003 caused at least 35,000 deaths (estimates go as high as 70,000) and a central Russian heat wave in 2010 may have caused 55,000 deaths (Houghton 2015). A famous 1995 heat wave caused hundreds of deaths in Chicago.

The place where heat waves will hit hardest, however, is in the tropics where heat stress is a daily occurrence.

A logical consequence of increased temperature is increased aridity in some places, e.g., the western US (Cook et al. 2004). Westerling et al. (2006) show that climate change in the western US has also resulted in longer fire seasons and more damaging wild fires.

Climate models have less reliability predicting specific regions that will be affected than global changes, but it is possible to make some reliable general predictions. The Hadley cells will expand and the jet streams and storm tracks will shift poleward (Yin 2005, Seidel and Randel 2007, Archer and Caldeira 2008). As the zones shift, the world's great desert areas will probably expand into subtropical areas.

As always, there will be winners and losers (Committee on Ecological Impacts of Climate Change 2008). Agriculture may become possible in areas that experience increased rainfall or warmth. For example, the Canadian prairies will have a longer growing season. Warmer winters at high latitudes may have some benefits such as reduced heating costs. On the other hand, native northern cultures often rely on sea ice for subsistence and build on permafrost, both disappearing as climate warms. The loss of Arctic coastal sea ice is creating accelerated shore erosion, requiring relocation of whole villages.

Regional climate will change, requiring adaptation of agriculture (Rosenzweig et al. 2000). Wise resource managers are already planning for the effects of climate change, regardless of what politicians say, e.g., Iverson et al. (1999). If rainfall decreases or fails to increase enough to compensate for increased evaporation, there must be increased reliance on irrigation. If surface water supply decreases, the deficit will have to be made up from groundwater or adoption of new water management techniques. Unfortunately, many aquifers are being depleted by withdrawals in excess of recharge in the face of diminishing surface water supplies, e.g., Borsa et al. (2014).

Climate remains an abstraction to many, but weather affects us all noticeably. Based on atmospheric physics, increased energy of a warmer Earth could easily make wilder, more energetic weather (Barry and Chorley 1998, Emanuel 2005, Knutson 1998, Webster 2005). For example, 2013 Typhoon Haiyan rendered more than two million people homeless and killed at least 6,000 in the Philippines and may have been the strongest cyclone to ever make landfall (Houghton 2015). Attributing extreme weather and other physical and biological anomalies to climate change (Rosenzweig et al. 2008), such as the "1,000-year" floods in South Carolina in 2015 (Wikipedia 2015) presents difficulties. The Committee on Extreme Weather Events and Climate Change (2016), however, reports rapid progress in the attribution of extreme weather events to climate change.

What is certain is that there will be great changes in ecosystems and a steep price to pay (Committee on Ecological Impacts of Climate Change 2008, Cowie 2007, Flannery 2005, King et al. 2006). There have been studies showing that the ranges of plants and animals will change, in some cases drastically (e.g., Field et al. 2006, Iverson et al. 1999, Matthews et al. 2004, Bradshaw and Holzapfel 2006). Animals are sometimes appearing in places they were unknown in the past (e.g., Field et al. 2006). Butterfly populations have shifted northward in response to climate warming and plants are showing phenological changes (such as breaking dormancy or flowering earlier than they have historically (e.g., Primack and Gallinat 2016). Plant ranges are changing dramatically, e.g., forests invading the southern edges of Arctic tundra.

Some of the worst consequences will be felt by plant and animal populations on isolated mountain peaks ("islands in the sky"). If bioclimatic zones shift too much vertically, such populations face certain extinction because they cannot migrate. Even many animal and plant populations that have apparently shifted easily in the past may be trapped by the human infrastructure (e.g., the interstate highway system) that impedes movement of land bound animals. Oceanic ecosystems are not immune to climate change either. Major changes associated with climate warming have occurred in the northern Bering Sea, for example (Grebmeier et al. 2006). Again, there will be winners and losers. The polar bear and many other species may become extinct, but history tells us that at least a few species will expand their populations and ranges.

At present we may be undergoing a mass extinction event (MacLeod 2013), and it does not help that the United States is the only major nation that has never participated in the Convention on Biological Diversity that has been signed by 193 other countries (Milius 2010). The current rapidity of climate change is a factor. Species that had 10,000 years to adjust to climate change in the past may have only 100 or ten years now. Humans can assist in the process of adaptation, but there is little indication of the will and certainly a lack of the necessary knowledge and resources to accomplish this task. The evidence is conflicting, but the combination of climate change and exploding human population that destroys habitat may lead to a mass extinction on the order of the one that occurred in the late Permian or at the K-T boundary (MacLeod 2013, Kolbert 2014). Avoiding current lesser extinctions has proven impossible (Bradshaw and Holzapfel 2006).

Of course, the damage to ecosystems will probably reduce the ability of the Earth to sustain life, reducing net productivity, at least temporarily. Humans will not escape the consequences of this ecological disaster because we depend on ecosystem services estimated to be at least equivalent in value to the world economy’s gross domestic product (Costanza et al. 1997). Current difficulties with the pollinators like honey bees (e.g., colony collapse disorder) that are absolutely essential to much of our crop production may be a prelude to much greater difficulties in the future.

When consequences of climate change begin to impact our security, you would expect the government to take note. In fact, the military is well aware of the destabilizing effects of climate change, including conflict over resources made scarcer and large refugee populations created by, e.g., coastal inundation, continual crop failures and natural disasters (CNA Corporation 2007). The Military Advisory Board, composed of general officers from the armed forces, perceives serious threats to our national security and recommends action to minimize climate change and mitigate the effects that are certain to occur (CNA Corporation 2007). A synthesis of studies on climate and human conflict found broad agreement that "Deviations from normal precipitation and mild temperatures systematically increase the risk of conflict, often substantially" (Hsiang et al. 2013).

The effects of climate change may bear most heavily on the poorest, who live in poverty in places where governments may lack the resources and competence to deal with the problems, especially effects of climate change on health, e.g., the spread of pathogens and vectors to new areas (Patz et al. 2005). Typically, these impoverished societies contribute much less to global warming than the more developed countries, which raises a question of fundamental fairness (Huntingford and Gash 2005).

Mitigation and Adaptation

Mitigation reduces the effects of climate change, primarily by decreasing emissions of GHG and maintaining or improving sinks that sequester CO_2. (IPCC WG III 2014). The primary action to effectively mitigate climate change clearly must be the rapid elimination of fossil fuels, the only practical way to stop the rise of CO_2 in the atmosphere. There are many nonpolluting sources of energy available: nuclear (fission and fusion), hydropower, solar, wind, geothermal, wave, tidal and ocean thermal. Biofuels can be used for applications such as aviation that require high density fuel. All energy sources have potential drawbacks, e.g., solar and wind require some form of storage for periods when the sun doesn't shine or the wind does not blow, hydropower can be reduced by extended drought, etc. Clearly, considering the potential consequences of climate change, the future will challenge humanity in incredibly stressful ways (Ramanathan and Feng 2008).

Atmospheric CO_2 has recently increased past the 400 ppm concentration and there has long been a consensus that anything more than 350ppm is dangerous and even 350 ppm may be too much (IPCC WG I 2013). It would be highly desirable, therefore, to find a way of removing CO_2 from the atmosphere and there has been some work done (Kramer 2008, Orr 2009, Schrag 2009), but little has been accomplished, unfortunately.

The Committee on Geoengineering Climate (2015a) reported that currently the most practical approach uses vegetation, e.g., reducing deforestation and promoting afforestation to remove CO_2 from the atmosphere (Kintisch 2009). Artificial approaches need intensive research to determine their practicality and explore different approaches to the problem. The committee also briefly compared the carbon sequestration approach to albedo modification, i.e., ways of reflecting sunlight to cool the Earth in this report. The committee emphasized, however, that elimination of CO_2 emissions must remain the highest priority, since that will almost certainly be the most practical and cost effective way of limiting climate change.

The Committee on Geoengineering Climate (2015b) also considered albedo modification as the primary focus in another report. Reflecting some incoming sunlight to cool the Earth, perhaps by introducing aerosols into the stratosphere, imitating volcanic eruptions such as Tambora in 1815 (Harington 1992, Stothers 1984), would be one approach. The committee concluded that albedo modification has considerable potential benefits, but also poses great risks of unintended consequences and needs extensive research into multiple possible approaches before deployment can be considered. The potential for creating problems that may be a feature of geoengineering should be examined thoroughly before implementation (Levi 2008, Shepherd et al. 2007). The

Committee on Geoengineering Climate (2015b) reiterated the need for eliminating emissions as the best current approach to solving the overall problem of climate change and limiting the damage incurred.

It must be emphasized that both mitigation and adaptation are needed to cope with the problem of climate change. The changes would continue and increase in the future, even if we were able to stop increasing the amount of atmospheric CO_2 immediately because the Earth system exhibits inertia (Houghton 2015, IPCC WG I 2013). For example, the ice caps will continue to melt until some new equilibrium is reached, which means that sea levels will continue to rise for the foreseeable future. Adaptation, therefore, is absolutely necessary. Human societies must increase their resilience to the changes and disasters that climate change brings. Without mitigation, however, adaptation is a futile attempt to adjust to a constantly worsening situation. In the worst case scenario, where the ice caps and mountain glaciers melt almost completely (raising sea levels more than 60m), the planet will not support even the present, let alone the projected population, billions would die and much of the infrastructure that our civilization has built and many of the resources we depend on would simply vanish under water.

Reasons for Delayed Action?

The effects of climate change have the potential to disrupt human civilization to a great degree. Given that scientists have actually had a good appreciation of the consequences of experimenting with our atmosphere in this manner since at least the 1960s (Weart 2015), why has there been little action to avert the worst consequences? This is a particularly relevant question since the required changes could have been phased in over a lengthy period and would have been much less disruptive than they will be, even if effective. On the other hand, technology has advanced remarkably in the last decade or two, e.g., innovations in solar and wind power. It is by no means certain that such advances were possible four or five decades ago without dedicating very large research efforts in those areas. This was unlikely, given that policy makers saw no cause for efforts to solve the problem at that time, although much could have been done to enhance efficiency that would have benefited the economy, no matter what transpired.

Unfortunately, as any psychologist will tell you, human rationality is a sometimes and fragile thing. Most people believe what they want to believe without regard to established scientific facts (McNall 2011, Washington and Cook 2011), a perfect example being belief that the Earth is only a few thousand years old, supposedly based on the Christian Bible, instead of the actual well established age of the Earth being some 4.5 billion years.

Gifford (2011) and Hulme (2009) have explored the reasons that people resist the need for mitigation and adaptation to climate change. One of the broad categories Gifford (2011) found included limited cognition. Limited cognition includes ignorance, judgmental discounting, optimism bias and uncertainty. There are many dimensions of ignorance and even people who know the most about the problem may not know how to solve it on a personal or institutional level. Judgmental discounting "... refers to the undervaluing of distant or future risks" (Gifford 2011, p. 292). This undervaluing of the future certainly applies to societies that see an environmental problem that threatens future wellbeing but cannot summon the resolve to take action to solve it (Diamond 2005), as well as to individuals.

Ideologies can provide powerful motivations both for and against climate action. The reliance on suprahuman powers (e.g., God or "Nature") to save us, the blind belief that technology will solve all our problems or belief in the existing system's ability to meet the challenge are some of the ideological deterrents to action on climate change (Gifford 2011, Hulme 2009). It should be noted that ideology can also be a force for action on climate change, e.g., the "Creation Care" movement which holds that people have a duty to limit climate change and protect biodiversity because it is a gift from God.

Gifford (2011) and Hulme (2009) see many other impediments to individual and collective action. Among them are behavioral momentum ("we've always done it this way"), financial investments of individuals and institutions (e.g., pension and mutual funds) and corporations (e.g., the fossil fuel industry), mistrust of groups or institutions (e.g., scientists, government agencies) and perceived risks of required changes. One of the psychological barriers is denial, the adamant refusal to believe facts. Those people and institutions who refuse to admit that climate change poses a potential threat to the planet and its inhabitants are clearly in denial.

There is an ethical dimension to the refusal to acknowledge the threat that climate change poses. Some people apparently anticipate that their great grandchildren or great, great grandchildren will have to cope with the first effects of climate change, pushing the problem far into the future and absolving them of any responsibility for taking action now. This is judgmental discounting (Gifford 2011). Many find that attitude to be morally reprehensible, even if it were true that the effects of climate change lie far in the future. As we have seen, however, that is definitely not true because we are experiencing the effects of climate change now and the effects will worsen.

Another aspect of the problem is that most people assume effects will be gradual, giving us abundant time to respond. They have experienced few of them or did not recognize them and probably do not pay attention to the amazingly rapid changes in the Arctic or other places (Hassol 2004). The assumption of gradual change, however, is definitely not valid (Alley et al. 2003, Clement et al. 2001). The potential for abrupt changes for which we are ill-prepared cannot be disregarded because such events do occur in the paleoclimatic record (Committee on Understanding and Monitoring Abrupt Climate Change and Its Impacts 2013).

Many people assume that conversion to a low/no carbon economy would be ruinous to the economy. In fact, detailed plans have been made and estimate that an 80% reduction in carbon emissions could be achieved by 2050, using less than 1% of our GDP (Williams et al. 2014). Enhancing efficiency across the board in housing and transportation, however, would pay economic dividends, even if climate change were not a serious threat.

Climate Change Denial

Climate scientists have reached a consensus that humans are changing the climate (Cook et al. 2013b; Oreskes 2004) and most scientists think that the changes will have a net detrimental effect on the planet in general and especially humanity. In view of the fact that without swift and decisive action we face possibly catastrophic changes, why have we not taken action? One answer is that the fossil fuel industry has taken a page from the tobacco industry playbook and funded efforts to obfuscate the facts, confuse the public and influence politicians (Oreskes and Conway 2010, Shulman 2008).

President Obama has accepted the facts presented by science and attempted to act on them through executive orders and the Environmental Protection Agency (EPA). Yet the Republican Party (labeled as "The Party of 'No'" by some commentators because of continual obstruction of federal operations, going so far as to shut down the government and threatening to default on the national debt) has resolutely refused to act, and, in fact, almost uniformly denies that the problem exists (Bradley 2011). Is this a universal characteristic of conservative parties globally?

A survey of the manifestos (in the US it is called a "platform") of conservative parties from nine geographically diverse modern industrial democracies (US, Canada, UK, Germany, Spain, Norway, Sweden, Australia, New Zealand) found that eight of the nine stated that anthropogenic climate change was a serious problem and needed urgent action to solve it, although they differed in their preferred approaches to solutions (Båtstrand 2015). The US Republican Party stands out in its refusal to accept the scientific consensus. This would be of little concern if the US played only a minor role in the world economy or if the US were not the largest per capita emitter of CO_2. Like it or not, our actions lead the world on this issue. What can explain this complete denial of reality by a US political party while other conservative parties accept the scientific consensus?

US conservatives have a long history of disregarding science when they perceive it to be in conflict with "conservative values" such as unregulated capitalism and anti-government individualism, as detailed in Bradley (2011), Mooney (2005), Oreskes and Conway (2010), Shulman (2008) and Washington and Cook (2011). Republicans tend to dismiss science as a liberal activity to be disregarded in favor of their ideological approach to the world as Mann (2012), Mooney (2005) and Shulman (2008) have shown. Unfortunately, Republican ideology favors "magical thinking" that disregards facts and established science (Mooney 2005, Shulman 2008, Washington and Cook 2011), e.g., the rationale for invading Iraq in search of weapons of mass destruction after the UN inspectors certified that their continuing exhaustive inspections had found none and scientists found their arguments for invasion lacking in foundation. This is a perfect example of Republican ideology leading them to risk catastrophic results with little regard for reality. It is now acknowledged that the invasion occurred in search of weapons of mass destruction thought by most intelligence analysts to be nonexistent. What is almost equally unbelievable, the invasion occurred without a plan for the occupation, which resulted in a lengthy and costly insurgency. The ideologically-driven misadventure in Iraq has created turmoil and destabilized the entire region, culminating in the rise of the Islamic State (ISIS) while costing the US dearly in terms of lives and treasure (Stiglitz and Bilmes 2008), and our involvement is ongoing.

Republican rejection of science may, in part, stem from their close association with business. Corporate interests frequently come in conflict with science that shows some products or practices to be dangerous. The pursuit of corporate profit seems to be a powerful incentive to disregard safety (Michaels 2008, Mooney 2005, Oreskes and Conway 2010). A good example is the demonization of Rachel Carson by the business community that began immediately before the publication of her book *Silent Spring* (1962). Carson has since been vindicated (e.g., Graham 1970) and the vilification shown to be motivated by protecting profits from the sale of harmful chemicals, e.g., DDT.

The inability of humans to change climate has become a set Republican ideological belief in the face of the massive scientific evidence that has accumulated over more than a century (Hay 2016, Washington and Cook 2011). I speculate that these false beliefs have been so amplified by talk radio and Fox News that, even if Republican leaders recognized the problem of climate change, they probably would not dare to articulate the truth to their voters. In fact, Republican politicians routinely misrepresent the truth about scientific facts, apparently in the belief that their voter base does not know enough to detect falsehoods (Mooney and Kirshenbaum 2009), or does not care (McNall 2011; Mooney 2005). Unfortunately, when Democratic President Clinton was in office he did little to advance solutions to the climate problem, I suspect because he anticipated Republican obstructionism.

Another factor is that many of the Republican voters are fundamentalist Christians who already reject well established science, e.g., the fact of evolution and the antiquity of the universe. With that set of beliefs, one could argue that those voters would have a propensity to reject scientific facts that their leaders reject (Kaufman 2010, Mooney and Kirshenbaum 2009) or that they find inconvenient for some reason, without any regard for objective truth.

There are some ideas common to those who deny human responsibility for climate change that prevent them from addressing the issue, such as rejection of the scientific literature as a product of conspiracy, making other problems (e.g., economics) more important, blind belief in the efficacy of free markets to solve all problems, and the view that people who want to protect the natural environment oppose all progress (McNall 2011). These views result in constant attacks on the Environmental Protection Agency and the Endangered Species Act as well as rejection of any action to combat climate change.

Diamond (2005) looks at historical examples of societies that encountered environmental problems that threatened their survival. Some, (e.g., the Greenland Norse) failed to comprehend the problems or would not take appropriate action. The Norse died out, but the Inuit thrived in the same deteriorating climate. Analogous mistaken attitudes and beliefs may actually endanger the future of human civilization (Inman 2009, Jamieson 2014).

Summary

There can be no doubt that human actions have greatly increased GHG in the atmosphere and that those GHG are warming the planet. We are already seeing the changes from this warming that diminish ice and snow, raise sea level, acidify the oceans, destroy biodiversity, disrupt ecosystems, intensify extreme weather and many other deleterious effects. These changes will accelerate and intensify, resulting in more climate refugees and increased conflict. Even if the world took decisive action now to stop GHG increases, there will be cascading effects that will make this planet a much less pleasant place to live. The Republican Party of the US has obstructed meaningful action for a variety of reasons and bears much of the responsibility for the consequences of inaction.

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Review

Age and Correlation of the Moorefield Shale (Upper Mississippian) in its Type Area, Northeastern Arkansas

O. Dalu[1], W.S. Coffey[2], and W.L. Manger[1]

[1]*Department of Geosciences, University of Arkansas, Fayetteville*
[2]*Devon Energy, Oklahoma City, Oklahoma*

Correspondence: wmanger@uark.edu

Running Title: Age and Correlation of the Moorefield Shale (Upper Mississippian), Northeastern Arkansas

Abstract

The name Moorefield was proposed by Adams and Ulrich (1904) for exposures of gray to brown, phosphatic shale with a basal limestone, overlying the Lower Mississippian Boone Formation, and underlying the Upper Mississippian Batesville Sandstone, in the vicinity of Moorefield, Independence County, northeastern Arkansas. Gordon (1944) 1) restricted the name Moorefield to the lower limestone-bearing interval, 2) applied a new name, Ruddell, to the succeeding shale section that comprises the bulk of the interval, with a type area near Moorefield, and 3) interpreted the interval contacts as unconformities. The name Ruddell was used for the revised Geological Map of Arkansas (1993), but later publications by the Arkansas Geological Survey and other sources refer the entire interval to the Moorefield Shale, and report a maximum thickness of 91.44 m. (300 feet).

Age assignments for the Moorefield Shale are based almost entirely on ammonoid cephalopods (*e.g.* Gordon 1965, Saunders et al. 1977, Korn and Titus 2011). Brachiopods (*e.g.* Girty 1911) have provided a supporting role, but never to the precision of the ammonoids. Initially, Gordon (1965) recognized two ammonoid zones and four subzones through all the Moorefield, except the base. Korn and Titus (2011) reexamined Gordon's published ammonoid assemblages, and made additional collections from the type Moorefield. They recognized only two Moorefield ammonoid zones: the lower *Goniatites eganensis* - *Girtyoceras welleri* zone, succeeded by the upper *Goniatites multiliratus* zone concentrated near the middle of the interval. The best age assignment for these abundant, middle Moorefield ammonoid assemblages is to the lower Chesterian Series (Korn and Titus 2011). The unfossiliferous lower Moorefield Shale spans the Meramecian-Chesterian boundary. The upper section, above the ammonoid occurrences, but also barren of ammonoids, and other biostratigraphically useful fossils, likely extends to at least the middle Chesterian. Thus, the bulk of the Moorefield formation represents the Chesterian, not the Meramecian Series. This age assignment is complicated further by the reduction of the lithostratigraphic units comprising the type Meramecian Series (Lane and Brenckle 2005), and a lack of ammonoid assemblages in its type area, St. Louis County, Missouri.

History of Moorefield Stratigraphic Investigations

The earliest record of systematic geological observations in northern Arkansas was by David Dale Owen, in a volume treating the northern counties published in 1858. Owen was appointed state geologist by Governor E. N. Conway on April 20, 1857. He arrived in Arkansas in early October, 1857, and began working in the northeastern corner, Greene County, proceeding westward across the northern two tiers of counties. The work was done on horseback and supported by horse-drawn wagons, focusing on potential economic mineral deposits. Independence County was the fourth county visited, and Owen's descriptions comprise eight pages of his first 256 page report (Owen 1858). Owen recognized the Archimedes Limestone (=Pitkin Limestone), and what is likely the Batesville Sandstone overlying a 9.14 m. (30 foot) section of brown-black shale with limestone intervals that is probably the Moorefield Shale, but did not name either interval. The northern counties report included at least some description of the geology of 18 counties. It was followed by a second report on the middle and southern counties, published in 1860 that concluded his survey of Arkansas. Owen died on November 13, 1860.

During Reconstruction, the Arkansas legislature appointed a series of state geologists and funded some geological work, but it was not until January 19, 1887 that an Arkansas Geological Survey was organized, with J. C. Branner as State Geologist, and a staff of young geologists that would become well-known in the profession. Again, the Survey was charged with an assessment of potential economic mineral occurrences, some of which had been identified by Owen (1858, 1860). In particular, the Survey was to evaluate the validity of a gold rush that had developed in the mid-1880s in the Ouachita Mountain region. In fact, the first publication of the new geological survey authored by T. B. Comstock (1888) exposed the Ouachita gold rush as a scam. On a brighter side, the Branner Survey hired the well-known geologist Richard Alexander Fullerton Penrose Jr. to investigate manganese occurrences in northeastern Arkansas, particularly the area surrounding Batesville, Independence County, that proved to be a legitimate resource.

The Penrose report (1891) was the first volume published by the Arkansas Geological Survey for work in 1890. It provided a stratigraphic column (Fig. 1), but from the current perspective, there are several problems. Most significantly, Penrose shows the Fayetteville Shale lying between the Boone Chert and the Batesville Sandstone in Independence County (Fig. 1). In fact, that shale has become known as the Moorefield Shale, while the Fayetteville Shale lies above the Batesville Sandstone. Penrose was a little closer to current thinking by assigning the Boone Chert and what would be Moorefield Shale to the Osagean Group, now Osagean Series, while the Batesville and Fayetteville intervals are assigned to the Genevieve or Boston Group, historically regarded as Meramecian (Fig. 1). Currently, the Fayetteville Shale is regarded as belonging to the Upper Chesterian Series.

The accepted naming and lithostratigraphic correlation of the Moorefield and associated units reflects the work of Adams and Ulrich on the lead and zinc deposits in northern Arkansas, published by the U.S. Geological Survey in 1904 (Fig. 2). Adams and Ulrich (1904) moved the Fayetteville to its proper position, and named the Moorefield Shale, indicating that it succeeded the underlying Boone Limestone unconformably, and was conformably overlain by the Batesville Sandstone (Fig. 2). They also included the Spring Creek Limestone Member at the base of the Moorefield that had been proposed by H.S Williams (1895). Unfortunately, the name Spring Creek was preoccupied by a unit of that name in the Pennsylvanian succession of Texas named by Noah Drake (1893), ironically the third chairman of the Department of Geology at the University of Arkansas. George H. Girty, a well-known U.S. Geological Survey paleontologist, published a description of the fauna of the Moorefield Shale in 1911. He reviewed the lithostratigraphic and chronostratigraphic age assignments for the Moorefield, although he retained the name “Spring Creek Limestone” of Williams (1895), even though he knew it was preoccupied, arguing that its chronostratigraphic importance outweighed an application of priority (Fig. 3). Girty (1911) was equivocal about age assignments for the interval, but concluded that the lower portion of the section, the Spring Creek Limestone, was Meramecian, based mainly on brachiopods. He correlated the higher portions of the Moorefield Shale with the Kaskaskia Limestone/Formation/ Group of Hall, 1857, which became the Chesterian Group of Worthen (1860), and later the Chesterian Series of Worthen (1866).

Mackenzie Gordon Jr. (1944), U.S. Geological Survey, reviewed the stratigraphic relationships of the

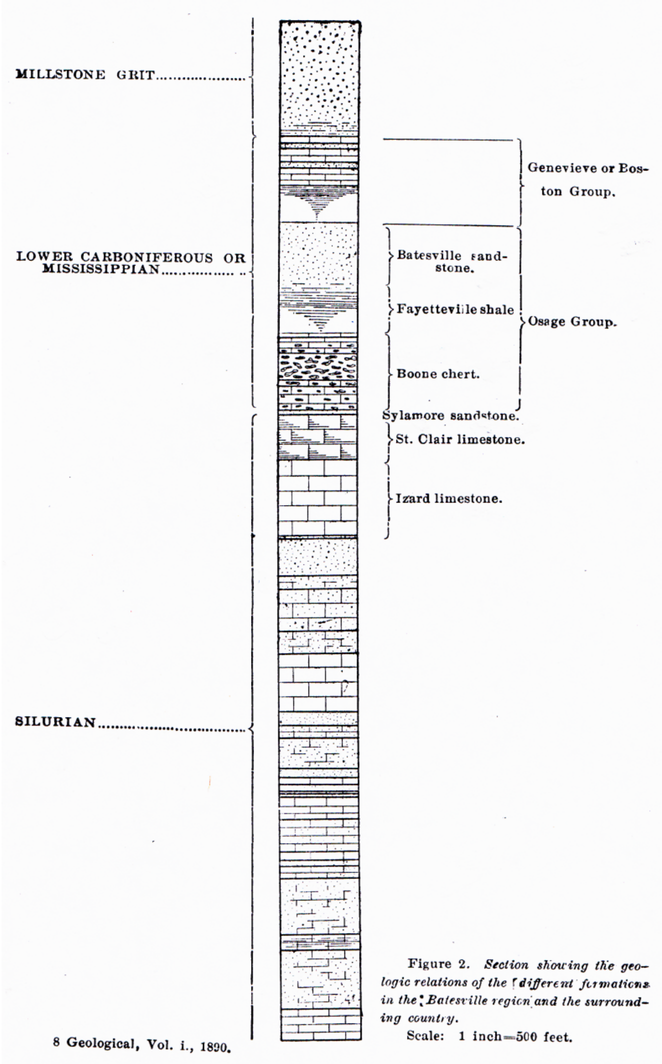
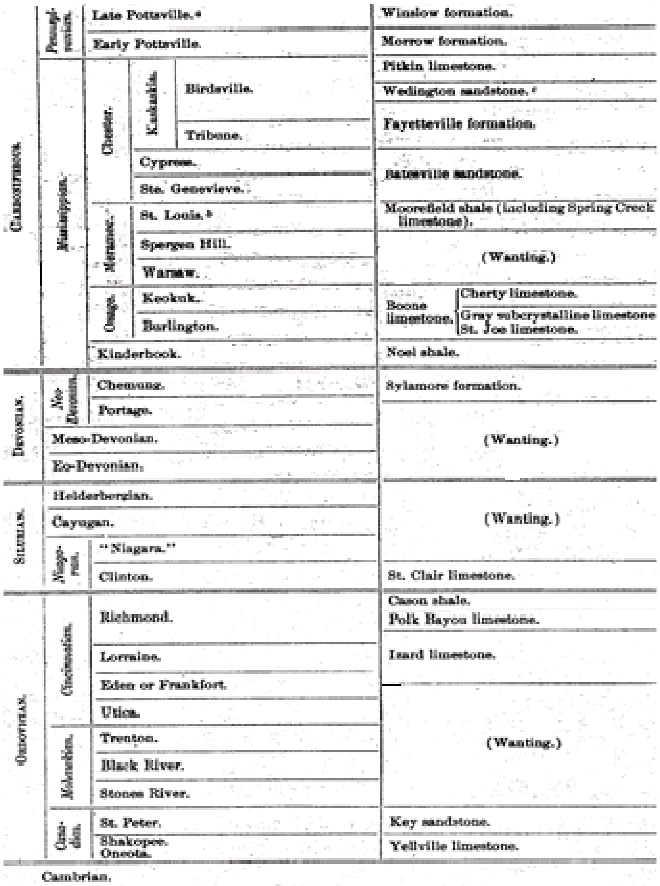


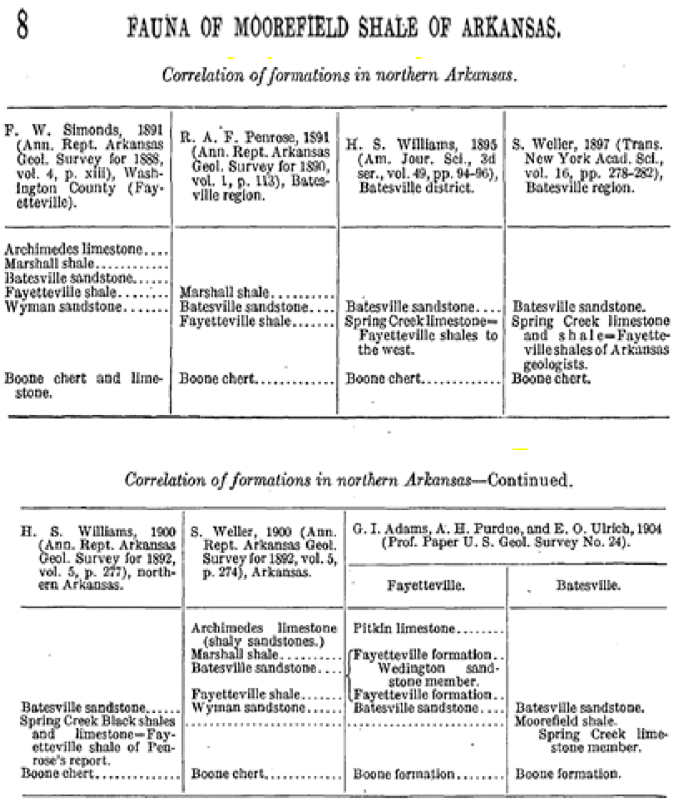
Fig. 1: Stratigraphic Section in the Vicinity of Batesville, Independence County (Penrose, 1891).



Carboniferous.	Pennsylvanian.	Late Pottsville.*			Winslow formation.
		Early Pottsville.			Morrow formation.
	Mississippian.	Chester.	Kaskaskia.	Birdsville.	Pitkin limestone. Wedington sandstone.* Fayetteville formation.
				Tribune.	
			Cypress.		Batesville sandstone.
			Ste. Genevieve.		
		Meramec.	St. Louis.*		Moorefield shale (including Spring Creek limestone).
			Spergen Hill.		(Wanting.)
			Warsaw.		
		Osage.	Keokuk.		Boone limestone. Cherty limestone.
			Burlington.		Gray subcrystalline limestone St. Joe limestone.
		Kinderhook.			Noel shale.
Devonian.	Neo-Devonian.	Chemung.			Sylamore formation.
		Portage.			(Wanting.)
	Meso-Devonian.				
	Eo-Devonian.				
Silurian.	Helderbergian.				(Wanting.)
	Cayugan.				
	Niagaran.	"Niagara."			
		Clinton.			St. Clair limestone.
Ordovician.	Cincinnatian.	Richmond.			Cason shale. Polk Bayou limestone.
		Lorraine.			Izard limestone.
		Eden or Frankfort.			(Wanting.)
		Utica.			
	Mohawkian.	Trenton.			
		Black River.			
		Stones River.			
	Canadian.	St. Peter.			Key sandstone.
		Shakopee. Oneota.			Yellville limestone.
Cambrian.					

Fig. 2: Stratigraphic Section for the Lead and Zinc Deposits in Northern Arkansas (Ulrich, in Adams 1904).

Moorefield interval in the Batesville Manganese District, Independence County. He restricted use of the name Moorefield to the black, calcareous shale and limestone at the base of the interval, previously called the Spring Creek Limestone, and proposed the name Ruddell to designate the succeeding shale interval that comprised most of the section. Gordon (1944) concluded that the restricted Moorefield correlated to the St. Louis Limestone, while the Ruddell was equivalent to the St. Genevieve Limestone, both assigned at the time to the Meramecian of the type Mississippi Valley section. That lithostratigraphic assessment continued into the 1960s, until Gordon (1965) published an extensive description of the Carboniferous ammonoid assemblages of Arkansas that he organized into zones and correlated to the type Mississippi Valley succession (Fig. 4). In this revision, Gordon (1965) regarded the Ruddell as spanning the Meramecian-Chesterian boundary, and interpreted the Moorefield lower and upper contacts as unconformities throughout most of their extent (Fig. 4).



8 FAUNA OF MOOREFIELD SHALE OF ARKANSAS.

Correlation of formations in northern Arkansas.

F. W. Simonds, 1891 (Ann. Rept. Arkansas Geol. Survey for 1888, vol. 4, p. xiii), Washington County (Fayetteville).	R. A. F. Penrose, 1891 (Ann. Rept. Arkansas Geol. Survey for 1890, vol. 1, p. 113), Batesville region.	H. S. Williams, 1895 (Am. Jour. Sci., 3d ser., vol. 49, pp. 94-96), Batesville district.	S. Weller, 1897 (Trans. New York Acad. Sci., vol. 16, pp. 278-282), Batesville region.
Archimedes limestone			
Marshall shale			
Batesville sandstone			
Fayetteville shale	Marshall shale		
Wyman sandstone	Batesville sandstone	Batesville sandstone	Batesville sandstone.
	Fayetteville shale	Spring Creek limestone=Fayetteville shales to the west.	Spring Creek limestone and shale=Fayetteville shales of Arkansas geologists.
Boone chert and limestone.	Boone chert	Boone chert	Boone chert.

Correlation of formations in northern Arkansas—Continued.

H. S. Williams, 1900 (Ann. Rept. Arkansas Geol. Survey for 1892, vol. 5, p. 277), northern Arkansas.	S. Weller, 1900 (Ann. Rept. Arkansas Geol. Survey for 1892, vol. 5, p. 274), Arkansas.	G. I. Adams, A. H. Purdue, and E. O. Ulrich, 1904 (Prof. Paper U. S. Geol. Survey No. 24).	
		Fayetteville.	Batesville.
	Archimedes limestone (shaly sandstones.)	Pitkin limestone	
	Marshall shale	Fayetteville formation Wedington sandstone member. Fayetteville formation	
	Batesville sandstone		
	Fayetteville shale		
Batesville sandstone	Wyman sandstone	Batesville sandstone	Batesville sandstone.
Spring Creek Black shales and limestone=Fayetteville shale of Penrose's report.			Moorefield shale. Spring Creek limestone member.
Boone chert	Boone chert	Boone formation	Boone formation.

Fig. 3: Review of Lithostratigraphic Nomenclature Applied to the Moorefield Interval in Northeastern Arkansas (Girty 1911)

Current Age Assignment of the Moorefield Interval, Northern Arkansas

Current age assignment for the Moorefield Shale is based almost entirely on ammonoid cephalopods (*e.g.* Gordon 1965, Saunders et al. 1977, Korn and Titus 2011). Brachiopods (*e.g.* Girty 1911) have provided a supporting role, but never to the precision of the ammonoids, and neither Moorefield conodonts nor palynomorphs have ever been evaluated. Korn and Titus (2011) reexamined Gordon's ammonoid assemblages, and made additional collections from the type Moorefield. They recognized two Moorefield ammonoid zones: the lower *Goniatites eganensis* - *Girtyoceras welleri* zone, succeeded by the upper *Goniatites multiliratus* zone. The best age assignment of these abundant Moorefield ammonoid assemblages occurring toward the middle portion of that stratigraphic interval is to the lower Chesterian Series (Korn and Titus 2011). Thus, the lower Moorefield Shale, as a low-stand wedge, must certainly span the Osagean-Meramecian boundary, even though barren. The upper section, also barren of ammonoids, and other biostratigraphically useful fossils, is unstudied,

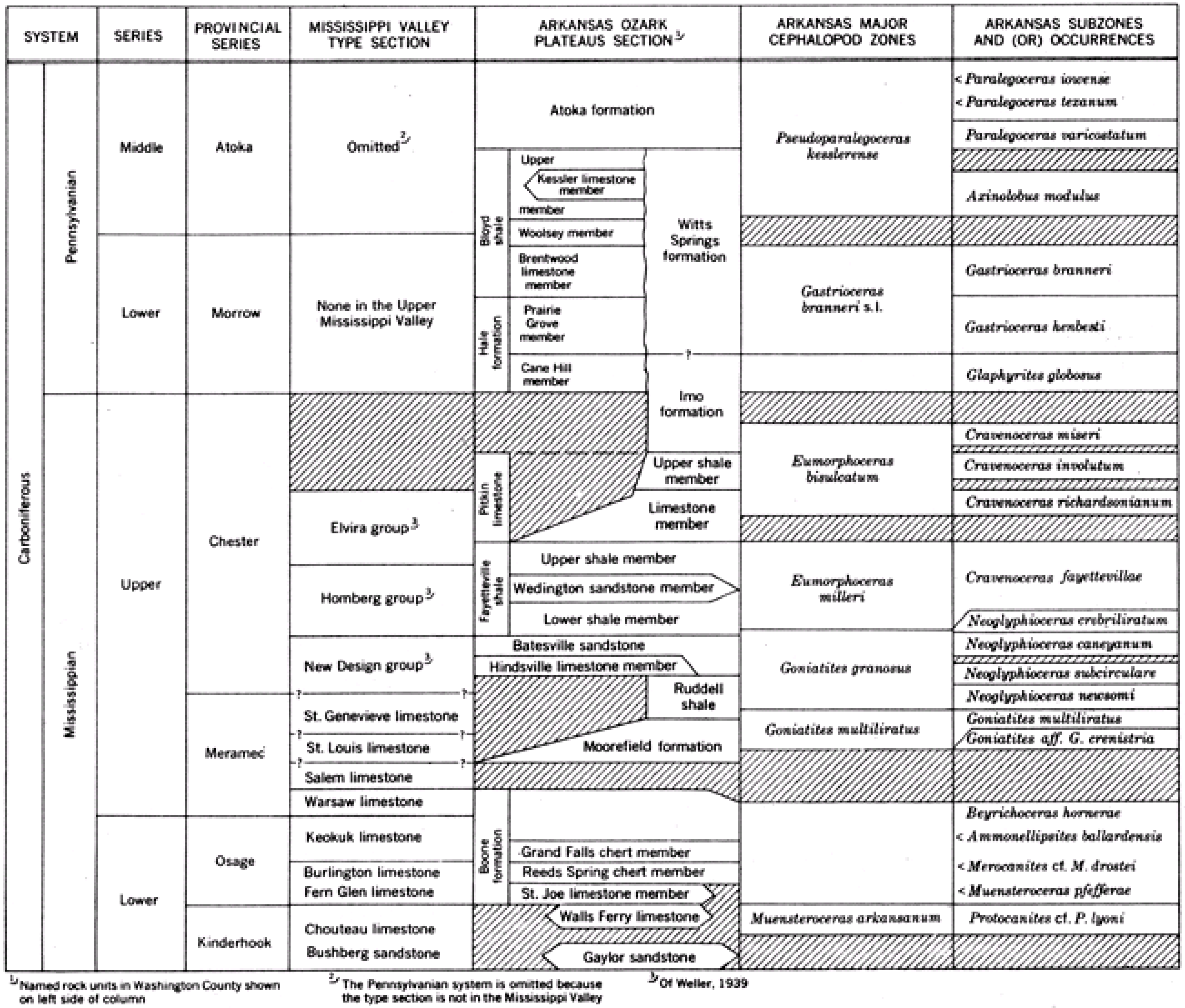


Fig. 4: Biostratigraphic and Chronostratigraphic Correlations for the Moorefield-Ruddell Interval, Northeastern Arkansas (Gordon 1965).

but is no older than middle Chesterian. Therefore, the Moorefield most likely spans the interval from early Meramecian to at least the middle Chesterian; the bulk of the formation represents the Chesterian, not the Meramecian, Series.

Duration of the Meramecian Series

The age assignment of the Moorefield interval is complicated further by a proposal to reduce the lithostratigraphic succession comprising the Meramecian Series (Lane and Brenckle 2005), and a lack of ammonoid assemblages in its type area, St. Louis County, Missouri. Lane and Brenckle (2005) placed the Osagean-Meramecian boundary at the contact of the lower and upper members of the Warsaw Shale. They also lowered the top of the Meramecian Series to the top of the St. Louis Limestone. Thus, the Ste. Genevieve, historically regarded as Meramecian, and which they contend is not present in the type area of the Meramecian Series, becomes part of the Chesterian Series. Consequently, the type Meramecian comprises only the upper Warsaw Shale, and Salem and St. Louis Limestones (Lane and Brenckle 2005).

This interval is zoned on conodonts, but the interval comprises only two zones: the *Gnathodus texanus* zone, which spans the Osagean-Meramecian boundary, and the *Hindeodus scitulus* and *Apatognathus scalenus* zone, which appears in the middle St. Louis Limestone and extends to its contact with the *Gnathodus bilineatus* zone in the succeeding Ste. Genevieve Limestone (Lane and Brenckle 2005). Thus, the Meramecian Series has no lower boundary defined by conodonts, and comprises essentially a single conodont zone. In comparison, the underlying Osagean Series and overlying Chesterian Series each comprise all or part of eight conodont zones (Lane and Brenckle 2005). The Meramecian Series must represent only half the absolute time of either the preceding Osagean Series, or succeeding Chesterian Series of the Mississippian Subsystem, and since 1983, the duration of the Mississippian Subsystem has been reduced to the current 35.7 my, a reduction of 4.7 my, for the International Chronostratigraphic Chart (Cohen et al. 2016). Although lacking precise absolute dates, the duration of the Meramecian would appear to be more consistent with a stage, rather than a series.

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Proportionality Between Population Descriptors (Covariables) in an Aggregated Acanthocephalan (Helminth) Infection of a Microcrustacean: Crofton Revisited

J.J. Daly Sr.* and K. Wagner

University of Arkansas for Medical Sciences (Retired)
J. J. Daly Sr. 6700 Grenada, Little Rock AR 72205

*Correspondence: jamesdalysr@yahoo.com

Running Title: Proportionality Between Population Descriptors in an Acathocephalan Helminth Infection

Abstract

We have previously shown that population parameters of the trematode metacercariae of *Clinostomum marginatum* in black bass (*Micropterus* spp.) were closely correlated with each other with the exception of prevalence (Daly et al. 2007, Daly (2014). Crofton (1971) and Haynes and Nicholas (1963) published raw data on an acanthocephalan, (*Polymorphus minutus*) in an amphipod intermediate host collected on 6 different sites on a stream. That data was used herein to examine similar correlations, as with *Clinostomum*, to see if another helminth infection, in this case from a different phylum, also had similar descriptor relationships. Forty one regression analyses were done on parameter data from the populations of *P. minutus* as described by Crofton and Haynes and Nichols. Descriptors used were mean abundance and standard deviation, maximum number, prevalence, mean intensity and standard deviation, dispersion coefficient, and skewness and kurtosis (shape parameters of the population curves). Results showed that the parameters most usually reported to describe helminth infections were, as with *Clinostomum*, strongly correlated with each other. One difference being prevalence, in which *P. minutus* prevalence was significantly correlated with other parameters.

Dispersion coefficients (standard deviation/mean) were independent (not significant) of an effect by the other parameters. Skewness and kurtosis were very highly correlated within the two population types (mean and mean intensity) but not with other descriptors. Since population parameters are important in the description of parasitic infections, it would seem that more data on more helminths are needed to determine if this proportionality is a universal phenomenon of stochastic and random helminth infections or just coincidentally found in *C. marginatum* and *P. minutus* juvenile infections.

Introduction

Daly et al. (2007) and Daly (2014) found that population descriptors, with the exception of prevalence, of the metacercariae of the parasite *Clinostomum marginatum* in black bass (*Micropterus* spp.) were highly correlated with each other. However, very little information regarding such correlations can be found in the literature of other parasitic helminth infections. The data of Crofton (1971) offered an opportunity to see if another helminth, this time a member of a different phylum, Acanthocephala, would also show such descriptor relationships (or not). Crofton published the raw data for populations of *Polymorphus minutus* infecting the intermediate amphipod hosts (*Gammarus pulex*) taken from 6 different downstream sites from the source of the definitive infection, a domestic duck farm. Crofton took raw data, originally published by Haynes and Nichols (1963), to develop an understanding of the mathematics involved in the infection and determined that the parasite population conformed to a negative binomial rather than a random distribution of parasites in the hosts. This is due to an overdispersion of the parasites where a few of the hosts contained a relatively large number of worms in contrast to the majority of the hosts. *Clinostomum* metacercariae in black bass also exhibit aggregation or overdispersion (Daly 2014) therefore it was of interest to see if the phenomenon of correlation between descriptors occurs in a similar negative binomial helminth infection. Using data from Crofton regression analyses were done between the descriptors where a correlation coefficient (R^2), an intercept, a slope, and a probability factor are obtained. The relative strength of the relationships can be compared with the regression coefficients and probability values. Predictive values can also be obtained for a dependent variable and examined for closeness of fit with the actual dependent values.

Methods and Materials

The raw data used for population descriptor determinations is from Crofton (1971). Determination of descriptors was done using Microsoft Excel descriptive statistic package. The descriptor values can be found in Tables 1 and 2. Table 1 contains the descriptors that are found in most population studies. Table 2 contains newer descriptors that are not usually seen in the literature. The data from those tables were used to calculate the correlations between the descriptors using the Microsoft Excel regression analysis package. Definitions of the descriptors followed that of Bush et al. (1997) with the exception of skewness and kurtosis which describes the geometry of the population curves. Skewness (SKEW) is the degree of distance from a hypothetical center of the curve and kurtosis (KURT) measures the height of the curve. Definitions of other descriptors and abbreviations are as follows: Mean abundance; the average number of parasites per host (MA and its standard deviation MASD), Maximum number; the largest number of parasites in a single host (MAX); Prevalence; Percent of hosts infected (PREV), Mean intensity; The average number of parasites per host but only for infected hosts (MI and its standard deviation, MISD) and dispersion coefficient; the degree of aggregation in the population (MASD/MA and MISD/MI). Also added was a geometric ratio; KURT/SKEW.

Results

Values taken from Crofton's raw data were used for both Excel descriptive statistics and regression analyses and can be found in Tables 1 and 2 with new data added. Skewness and kurtosis are new correlations as are mean intensity and its standard deviation.

Table 1. Population descriptors for the acanthocephalan *Polymorphus minutus* in *Gammarus pulex* (data recalculated from Crofton 1971). MA = mean abundance, MASD = MA standard deviation, MAX =maximum number, MI = mean intensity, and MISD = MI standard deviation).

Site	No. Hosts	Prevalence	MA	MASD	MAX	MI	MISD
1	547	70.9	2.28	2.35	10	3.2	2.2
2	509	63.0	1.42	1.62	9	2.3	1.5
3	633	27.7	0.60	1.2	7	2.2	1.5
4.	486	66.0	1.31	1.37	8	2.0	1.2
5	276	48.9	0.89	1.22	6	1.8	1.2
6	191	20.0	0.27	0.62	4	1.3	0.7

Table 2. Population descriptors for the acanthocephalan *Polymorphus minutus* in *Gammarus pulex* (data calculated from descriptors (independent variables) in Table 1 and new data: Dispersion ratios (MASD/MA, MI/MISD); and population curve characteristics of Skewness (SKEW) and Kurtosis (KURT). MA = mean abundance, MASD = MA standard deviation, MAX =maximum number, MI = mean intensity, and MISD = MI standard deviation).

Site	MASD/MA	MISD/MI	MA SKEW	MA KURT	MI SKEW	MI KURT
1	1.03	0.69	1.08	0.61	1.00	0.49
2	1.14	0.65	1.47	2.73	1.61	3.17
3	2.00	0.68	2.59	7.07	1.37	1.36
4	1.04	0.60	1.22	1.56	1.43	2.20
5	1.37	0.66	1.70	2.90	1.56	1.96
6	2.22	0.54	2.94	10.32	2.28	5.15

Dispersion coefficients for both mean abundance and mean intensity are also new and calculated with mean abundance standard deviation/mean abundance (MASD/MA) and mean intensity standard deviation/ mean intensity (MISD/MI). These coefficients can determine the degree of dispersion of the population. Greater than 1 is overdispersion and less than 1 is tending toward random distribution. It can be seen that the MASD/MA of the unredacted data shows overdispersion (Table 1). The average and standard deviation of the 6 sites is 1.66±0.85. However, removing all zeroes (uninfected) from the host population (MI) increases the population mean to an average of 2.13±.66 producing a random distribution of parasites in the host population.

Forty two regression analyses were done. The independent variable of each set was always what was considered to be the major descriptor of the relationship: mean abundance, and standard deviation, maximum number, mean intensity and mean intensity standard deviation. The results of the regressions can be found in Tables 3 and 4. Table 3 regressions are those that are considered to be the usually reported descriptors found in most publications with the addition of dispersion coefficients of MASD/MA, MISD/MI. Table 3 regressions are those involving the descriptors found in Table 2 and the population distribution curves geometric analyses of skewness and kurtosis are in Table 4. The correlations in the Tables were ranked based on the strength of the probability coefficient for significance and for Table 3 ranged from 8E-05 to 0.35. Using 0.05 as the standard for statistical significance the strongest correlations were those variables that are considered to be somewhat

Table 3. Regression values for population descriptors for *Polymorphus minutus* infection in *Gammarus pulex*. Calculations were made using the data in Table1. Abbreviations can be found in Tables 1 and 2.

Independent variable	Dependent variable	R²	Intercept	Slope	*p*
Mean Intensity	Mean Intensity SD	0.99	-0.28	0.78	8E-05
Mean Abundance	Mean abundance SD	0.95	0.53	0.76	0.001
Mean Abundance SD	Mean Intensity	0.94	0.64	1.10	0.0013
Mean Abundance SD	Mean Intensity SD	0.91	0.23	0.83	0.003
Mean Abundance SD	Maximum Number	0.88	2.30	3.57	0.006
Mean Intensity	Maximum Number	0.84	0.66	3.10	0.01
Mean Abundance	Maximum Number	0.83	4.30	2.70	0.01
Mean Abundance	Prevalence	0.82	19.80	26.00	0.014
Mean Abundance	Mean Intensity	0.82	1.20	0.78	0.014
Mean Abundance	Mean Intensity SD	0.75	0.72	0.58	0.03
Mean Abundance	SD/Mean Abundance	0.74	2.20	-0.63	0.03
Maximum Number	SD/Mean Abundance	0.69	3.00	-0.21	0.040
Mean Abundance SD	Prevalence	0.69	6.40	30.80	0.042
Mean Intensity SD	SD/Mean Intensity/MI	0.66	0.51	0.09	0.048
Mean Abundance SD	SD/Mean Abundance	0.64	2.50	-0.76	0.057*
Mean Intensity	SD/Mean Intensity	0.56	0.49	0.06	0.18*
Mean Intensity	Prevalence	0.47	-0.04	23.20	0.13*
Mean Abundance SD/MA	Mean Intensity SD/MI `	0.22	0.71	-0.05	0.35*

*Not significant with *p* = 0.05

required for any description of a parasitic helminth population (mean abundance, mean abundance standard deviation, maximum number, prevalence and in many publications, mean intensity values). Only four of these regressions were not significant. Of these, three had as one of the variables a coefficient of dispersion. The other non-significant correlation, which did not include a dispersion coefficient, was mean intensity versus prevalence. Prevalence in this latter correlation uses the non-redacted data and does not mean intensity prevalence which is 100% for all sites. Since prevalence does not change for the MI populations it can be assumed beforehand that this relationship should not be significantly correlated. This relationship (PREV vs. MI) deals with an artificially modified population (mean intensity) of the original nonredacted population and acts as a control on the efficacy of the regression analyses. Surprisingly dispersion coefficients are somewhat independent of the mean and standard deviation (and MISD and MI) which are both used to calculate the dispersion coefficients. Table 4 included the regressions involving skewness and kurtosis as the dependent variables. These ranged from 7.9E-05 to 0.46. The strongest relationships were between skewness and kurtosis (both mean abundance and mean intensity populations). Eight of the correlations were not significant based on $p = 0.05$. Prevalence and skewness or kurtosis showed surprisingly strong correlations with Mean abundance (MA). Other descriptors paired with skewness and kurtosis were either slightly significant, $p = 0.041$ to 0.048, or not significant. Therefore skewness and kurtosis are somewhat independent of the other descriptors except for each other. A caveat for all these regressions is that only 6 samples (n =sites) are used for each variable. Such a small sample size emphasizes the significance of some of the comparisons.

Discussion

Almost any study of a parasitic helminth population includes descriptive parameters. These are used to monitor changes in the population and/or compare populations to see if they are different. Any additive information regarding these parameters or the introduction of newer available parameters (skewness and kurtosis) would assist investigators of helminth populations in achieving the above goals. Poulin (2007) performed a review of these descriptors and the possible reasons to explain the variety of results that parasite populations have shown. Such factors as parasite density dependent, density independent, immune response of hosts, fecundity, mortality, host size, recruitment and environmental impact are all considered. Daly (2014) found with the yellow grub (Clinostomum) that metacercarial infections in smallmouth bass (Micropterus dolomeiu) showed strong proportionality between descriptors, so much so that the regression coefficients were strongly predictive within the populations. Prevalence was not well correlated with other descriptors but this is due to the high parasite density in some of the populations where parasites can reach 100% prevalence but parasite abundance can still keep increasing (Daly and Wagner, *in prep*.). With the Polymorphus minutus regressions the parameters were almost all significantly correlated with the exception of standard deviation/mean and some geometric values (kurtosis and skewness). This makes Polymorphus the second helminth to have these population proportionality characteristics. Although in two different phyla both P. minutus and C. marginatum are similar and dissimilar in important ways. Both studies used juvenile worms in intermediate hosts. Neither worm reproduces in that host. Both studies used different sites on a stream, the difference being that P. minutus decreases overall infection density as it progresses downstream and C. marginatum increases overall abundance downstream. However, both parasites exhibit overdispersion or a negative binomial dispersion. Redacting zero infected hosts (MI) in both infections produces a normal distribution but still does not alter basic correlations, except for skewness and kurtosis and the contrived standard deviation/ mean ratio. Why parasitic helminth populations favor a negative binomial distribution over random distribution is not clear (Poulin 2007) but Daly (2007) has proposed that in many cases that the most heavily infected hosts are closer to the source of the infection and the less infected hosts are further away. Parasites and hosts are not randomly or evenly distributed in the environment. In the case of C. marginatum the important factors would be the presence of infected snails with a nearby population of definitive hosts (great blue herons). The infecting zone would then be determined by stream hydraulics and the path of the migrating cercaraie. With *P. minutus* stream hydraulics would be the most important factor since eggs of *P. minutus* are inert and dependent for distribution on a current. It is known that stream flow is different from area to area in a stream and the position and numbers of the microcrustacean hosts in those zones would be the major determinate for infection and an aggregate distribution in the hosts.

Table 4. Regression values for population descriptors using data for SKEW and KURT, for *Polymorphus minutus* infection in *Gammarus pulex*. Calculations were made using the data in Table 1 and 2. Abbreviations can be found in Tables 1 and 2.

Independent variable	Dependent variable	R^2	Intercept	Slope	*p*
Skewness (MA)	Prevalence (MA)	0.99	100.0	-28.0	7.9E-05
Skewness (MA)	Kurtosis (MA)	0.97	-4.7	4.9	0.0003
Skewness (MI)	Kurtosis (MI)	0.94	-3.3	3.7	0.001
Kurtosis (MA)	Prevalence (MA)	0.93	72.6	-5.5	0.002
Kurtosis/Skewness (MA)	Prevalence (MA)	0.89	86.6	-19.4	0.004
Kurtosis/Skewness (MA)	Abundance (MA)	0.85	2.3	-1.63	0.01
Mean Intensity SD	Skewness (MI)	0.82	2.6	-0.77	0.014
Mean Intensity	Skewness (MI)	0.79	2.8	-0.59	0.02
Abundance (MA)	Skewness (MA)	0.78	2.9	-0.91	0.03
Abundance (MA)	Kurtosis (MA)	0.74	9.2	-4.4	0.03
Mean Intensity SD	Kurtosis (MI)	0.70	6.2	-2.7	0.04
Maximum Number	Kurtosis (MA)	0.69	14.7	-1.43	0.041
Maximum Number	Skewness (MA)	0.69	4.0	-0.29	0.043
Mean Abundance SD	Kurtosis (MA)	0.68	11.7	-5.4	0.041
Mean Abundance SD	Skewness (MA)	0.66	3.3	-1.1	0.049
Mean Intensity	Kurtosis (MI)	0.64	6.8	2.1	0.051*
Kurtosis/Skewness (MI)	Abundance (MI)	0.61	3.1	-0.8	0.07*
Kurtosis (MA)	Skewness (MI)	0.61	1.2	0.06	0.07 *
Skewness (MA)	Skewness (MI)	0.50	-0.15	1.28	0.11*
Kurtosis (MA)	Kurtosis (MI)	0.47	1.1	0.3	0.13*
Skewness (MI)	Prevalence (MA)	0.47	102.6	-34.5	0.13*
Skewness (MA)	Kurtosis (MI)	0.34	0.11	1.2	0.22*
Kurtosis (MI)	Prevalence (MA)	0.29	66.2	-7.0	0.27*
Kurtosis/Skewness (MI)	Prevalence (MA)	0.14	67.7	-12.4	0.46*

*Not significant with $p = 0.05$

Possibly the faster flow would contain more eggs and a slower flow more *Gammarus.*

Nevertheless, regardless of the parasite distribution in the host population, it appears that because of the proportionality that the same factors are at work at different sites, in this case on streams. Daly (2014) has compared the proportionality to that of nesting Russian dolls. They look similar except for size but proportionally they look the same. It is interesting that even the geometry (kurtosis and skewness) of the population curves change proportionally to abundance changes. It would seem that more studies of this proportionality phenomenon are needed and would add important data to metazoan parasite infections. The most important impediment factor for such studies is to have enough different sites to regress with markedly different population intensities.

Conclusion

To summarize: Significant correlations are seen between the major population descriptors of MA, MASD, MAX, MI, MISD, and PREV. Dispersion coefficients correlate poorly or are not significant with other descriptors. Skewness and kurtosis (both MA and MI) correlate well with prevalence, MA, MI, MISD; However they do not correlate significantly with other descriptors including most of the standard deviations but are closely correlated with each other within the same population (MA SKEW vs MA KURT, MI SKEW VS MI KURT).

This is only the second parasitic helminth to exhibit so many such significant correlations. It implies that the factors producing this uniformity are the same, for the most part, at different population sites with different parasite densities. The aggregated populations may be a result of a similar spaciality between host and source of infection at each of the different sites.

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Water-quality Effects on Phytoplankton Species and Density and Trophic State Indices at Big Base and Little Base Lakes, Little Rock Air Force Base, Arkansas, June through August, 2015

L.J. Driver* and B.G. Justus

U.S. Geological Survey, Lower Mississippi-Gulf Water Science Center, 401 Hardin Rd., Little Rock, AR 72211

*Correspondence: ldriver@usgs.gov

Running title: Nutrients, Phytoplankton, and Trophic State Index in Small Lakes on Little Rock Air Force Base

Abstract

Big Base and Little Base Lakes are located on Little Rock Air Force Base, Arkansas, and their close proximity to a dense residential population and an active military/aircraft installation make the lakes vulnerable to water-quality degradation. The U.S. Geological Survey (USGS) conducted a study from June through August 2015 to investigate the effects of water quality on phytoplankton species and density and trophic state in Big Base and Little Base Lakes, with particular regard to nutrient concentrations. Nutrient concentrations, trophic-state indices, and the large part of the phytoplankton biovolume composed of cyanobacteria, indicate eutrophic conditions were prevalent for Big Base and Little Base Lakes, particularly in August 2015. Cyanobacteria densities and biovolumes measured in this study likely pose a low to moderate risk of adverse algal toxicity, and the high proportion of filamentous cyanobacteria in the lakes, in relation to other algal groups, is important from a fisheries standpoint because these algae are a poor food source for many aquatic taxa. In both lakes, total nitrogen to total phosphorus (N:P) ratios declined over the sampling period as total phosphorus concentrations increased relative to nitrogen concentrations. The N:P ratios in the August samples (20:1 and 15:1 in Big Base and Little Base Lakes, respectively) and other indications of eutrophic conditions are of concern and suggest that exposure of the two lakes to additional nutrients could cause unfavorable dissolved-oxygen conditions and increase the risk of cyanobacteria blooms and associated cyanotoxin issues.

Introduction

Eutrophication, the process by which primary production in aquatic ecosystems is increased by nutrients, poses a widespread threat to water quality in both freshwater and marine ecosystems (Smith et al. 1999). The potential consequences of eutrophication include excessive plant/algal growth, harmful algal blooms (HABs), dissolved-oxygen (DO) depletion (anoxia), fish kills, alteration of food webs, and loss of ecosystem services such as fish consumption and recreational amenities (Smith et al. 1999, Carpenter 2005). Cyanobacterial harmful algal blooms (cyanoHABs) can result in low and unstable DO concentrations, possible toxic conditions for humans and animals, and negative effects on fish biomass and density (Lee et al. 1991).

Primary production (i.e. phytoplankton stimulus), which is often limited by nitrogen, phosphorus, or light, is a key determinant of fish density and diversity in streams and lakes (Downing and Plante 1993). Because phytoplankton are the base of freshwater food webs, the growth, survival, and biomass of fish in lakes are often correlated with phytoplankton density (Oglesby 1977, Downing et al. 1990, Diana et al. 1991). Thus, fish production generally increases as lakes become more eutrophic (Bachmann et al. 1996).

Big Base and Little Base Lakes, located on the Little Rock Air Force Base (LRAFB, Fig. 1) in Arkansas, are used for recreational fishing and other recreational activities (e.g. kayaking). In addition, these lakes provide forage (fish) for a federally endangered Interior Least Tern (*Sterna antillarum athalassos*) population that nests annually on the LRAFB. Close proximity to a residential population and an active military aircraft installation make Big Base and Little Base Lakes vulnerable to water-quality degradation. Assisting Federal resource managers is an important part of the USGS mission, and previous studies conducted by the USGS have indicated that both lakes are susceptible to eutrophication (Justus 2005). Periodic assessments of biological and chemical conditions are necessary to monitor changes in water quality and to support future decisions and management efforts in both lakes.

The purpose of this study was to investigate water quality, phytoplankton, and trophic-state in Big Base and Little Base Lakes to assess their relations with eutrophication, cyanoHABS, and potential risks to humans and wildlife. Information provided in this article will provide a baseline to which LRAFB personnel can compare future water-quality conditions, thereby enabling them to make informed decisions for managing nutrients and fish and wildlife resources in the two lakes.

Materials and Methods

Study area

Located northeast of Little Rock, Arkansas (Fig. 1), LRAFB sits along the fall line between the Ozark Highlands and the Mississippi Alluvial Plain. The LRAFB covers approximately 24.3 km^2 and accommodates more than 11,000 military and civilian personnel, several thousand of which live on base (United States Air Force 2016). Big Base and Little Base Lakes are located near the western boundary of LRAFB and are connected by a culvert beneath Arnold Drive (Fig. 1; Table 1). Under normal lake conditions, the surface areas of Big Base Lake and Little Base Lake are approximately 16 hectare and 0.5 hectare, respectively (Justus 2005). The land surrounding the lakes comprises suburban development (residential and commercial), aircraft installations, and small forested tracts.

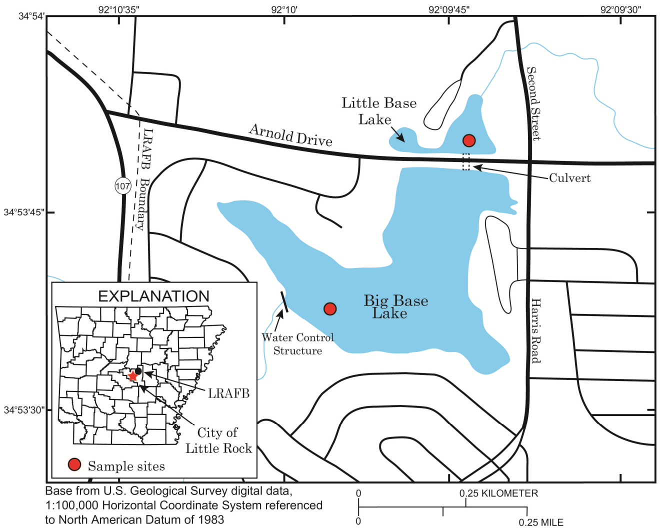

Figure 1. Map of sample site locations in Big Base and Little Base Lake, Little Rock Air Force Base, Arkansas, 2015.

Table 1. Site information for two lake sites sampled at Little Rock Air Force Base, Arkansas, 2015. Latitude and longitude coordinates are relative to the North American Datum of 1927 (NAD 27). [USGS, U.S. Geological Survey]

Site name	USGS station number	Latitude	Longitude
Big Base Lake	07263924	34° 53' 38"	92° 09' 57"
Little Base Lake	07263922	34° 53' 50"	92° 09' 43"

Field Collections

The USGS collected water-quality and phytoplankton samples from Big Base and Little Base Lakes three times each during the summer of 2015 (June 4, July 9, and August 20). The Big Base Lake sample site was located at the deepest part of the lake (depth approximately 6 m) east of the water-control structure (Fig. 1). The Little Base Lake sample site was located near the center of the lake where the depth was approximately 1 m. Vertical-depth profiles of DO, pH, specific conductance, turbidity, and water temperature were measured at 0.3-m depth intervals with a calibrated multiparameter water-quality monitor in both lakes on each sampling date. Transparency (optical clarity) was measured with a Secchi disk.

Water-quality samples were collected and processed according to USGS protocols (Wilde et al. 1999, Green et al. 2015). Water samples for nutrient concentrations, phytoplankton composition, and chlorophyll *a* were collected by pumping water to the lake surface using a peristaltic pump and weighted hose. In Big Base Lake, water was pumped from a depth approximately midway (1.0-1.5 m) through the epilimnion (the uppermost thermal stratification layer), whereas water from Little Base Lake was pumped from a depth midway through the water column (approximately 0.6 m). In addition, field observations were recorded for lake appearance and weather characteristics.

Laboratory Processing and Analysis

Water-quality constituents were selected for sampling and analysis based on their potential relation and impact on phytoplankton density and lake trophic status (Wetzel 2001). Nutrient constituents included total nitrogen, dissolved ammonia, dissolved nitrite plus nitrate, organic nitrogen, dissolved orthophosphate, and total phosphorus. Total nitrogen represents combined forms of organic and inorganic nitrogen (i.e. nitrite plus nitrate and ammonia nitrogen). Organic nitrogen was calculated as total nitrogen minus the total concentrations of nitrite plus nitrate and ammonia. If either nitrite plus nitrate or ammonia concentrations were below laboratory detection levels, the range of organic nitrogen concentrations was reported as total nitrogen minus the lowest (i.e. zero) and highest (i.e. detection level) concentrations of each constituent. Water-quality samples for chemical analyses were shipped overnight on ice (on the date of collection) to the USGS National Water Quality Laboratory (NWQL) in Lakewood, Colorado, and analyzed following USGS procedures (Fishman 1993). Phytoplankton were identified and counted in a laboratory at the University of Arkansas at Little Rock by USGS personnel (Dr. Reed Green) using the inverted-microscope method described by Britton and Greeson (1989). Calculations of cell/colony biovolume (mm^3/L) for each algal taxa followed formulas in Kellar et al. (1980). Water-quality and depth profile data used in support of this article are available from the USGS National Water Information System (U.S Geological Survey 2016).

Concentrations of total phosphorus and chlorophyll *a* and Secchi depth measurements are often related to algal density. Because algal density increases in response to increased productivity, Carlson's trophic state index (TSI) values calculated using phosphorus, chlorophyll *a*, and Secchi depth measurements are often used to determine trophic status (oligotrophic <40; mesotrophic 40-49; eutrophic 50-69; hypereutrophic ≥70 (Wetzel 2001)). Carlson's TSI values were calculated from total phosphorus and chlorophyll *a* concentrations, and Secchi depth measurements using the following equations:

$$\text{TSI (TP)} = 14.42 \ln(TP*1000) + 4.15 \quad (1)$$

$$\text{TSI (CHL)} = 9.81 \ln(CHL) + 30.6 \quad (2)$$

$$\text{TSI (SD)} = 60 - 14.41 \ln(SD) \quad (3)$$

where TP is total phosphorus concentration (milligrams per liter), CHL is chlorophyll *a* pigment concentrations (micrograms per liter), SD is Secchi depth measurement (meters, m) (Carlson 1977), and ln is the natural logarithm. The TSI can be used to assess lake productivity along a continuum of trophic states assuming that lakes age in progression from oligotrophic (i.e. low nutrient input, low productivity) to eutrophic (i.e. high nutrient input, high productivity; Wetzel 2001).

Results

Vertical water-temperature profile measurements indicate that Big Base Lake was thermally stratified on all three sampling dates during the summer of 2015. Maximum surface temperatures ranged from 24.4 to 27.9 °C, whereas minimum bottom temperatures ranged from 11.6 to 13.6 °C. Changes in water temperature near the thermocline in Big Base Lake were more gradual on August 20 compared to the two prior sampling events (less than 1 C° change over a depth of almost 1 m, compared to more than 1 C° over 0.6 and 0.3 m for June and July, respectively). DO concentrations ranged from 0.1 to 9.4 mg/L across all depths, with concentrations generally less than 3.0 mg/L below the 2-m depth in each monthly sample. Values of pH varied little across depth and ranged from 6.4 to 7.5 in the epilimnion. Median pH over the sampling period was 6.2 across all depths. Turbidity

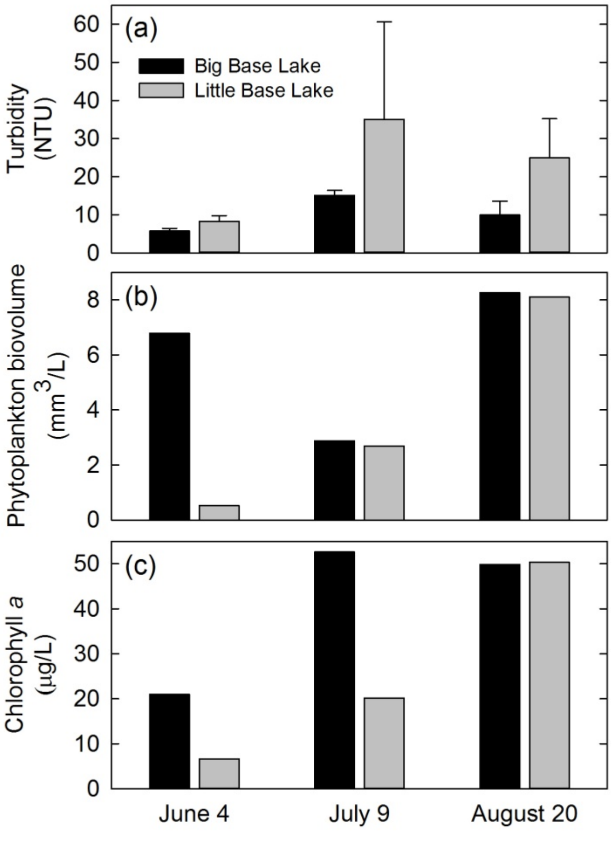

Figure 2. Bar graphs indicating mean (±SD) water column turbidity, total phytoplankton biovolume, chlorophyll *a* and for samples collected from June through August, 2015 in Big Base and Little Base Lakes, Little Rock Air Force Base, Arkansas. [NTU, nephelometric turbidity units; mm^3/L, millimeters cubed per liter; µg/L, micrograms per liter]

Table 2. Laboratory results for selected nutrients from water samples collected from Big Base and Little Base Lakes, Little Rock Air Force Base, Arkansas, June through August, 2015. [<, censored values at or below laboratory minimum detection limit; mg/L, milligrams per liter; N, nitrogen; P, phosphorus]

	Sample date	Organic nitrogen[1] (mg/L)	Ammonia, dissolved (mg/L as N)	Nitrite plus nitrate, dissolved (mg/L as N)	Total nitrogen (mg/L)	Total phosphorus (mg/L)	Ortho-phosphate, dissolved (mg/L as P)
Big Base Lake	June 4	0.29-0.34	<0.01	<0.04	0.34	0.006	<0.004
	July 9	0.30-0.35	<0.01	<0.04	0.35	0.008	<0.004
	Aug. 20	1.0-1.1	0.13	<0.04	1.2	0.06	<0.004
Little Base Lake	June 4	0.33-0.38	<0.01	<0.04	0.38	0.014	0.006
	July 9	0.37-0.42	0.02	<0.04	0.42	0.017	<0.004
	Aug. 20	1.1	0.11	<0.04	1.2	0.084	<0.004

[1] Organic nitrogen was calculated as total nitrogen minus the total concentrations of ammonia plus nitrite and nitrate. If either ammonia or nitrite plus nitrate concentrations were below laboratory detection levels, the range of organic nitrogen concentrations was reported as total nitrogen minus the lowest (i.e. zero) and highest (i.e. detection level) concentration of each constituent.

differed between the three monthly samples (Fig. 2a), but turbidity in Big Base Lake was fairly uniform throughout the water column profile on June 4 (mean = 5.7 ± 0.7 nephelometric turbidity units (NTU)) and July 9 (15.1 ± 1.3 NTU). In contrast, turbidity was stratified on August 20 and averaged 13.5 NTU in the epilimnion compared to 6.7 NTU in the hypolimnion (depths below 2.4 m), with an overall mean of 9.9 ± 3.6 NTU. Secchi depth measurements decreased from 1.09 m on June 4, to 0.96 m on July 9, to 0.48 m on August 20.

Little Base Lake was shallow (~0.7-1.4 m) and was not thermally stratified during the three sampling events. Water-quality constituents in Little Base Lake were generally similar to surface readings from Big Base Lake: mean values for temperature and DO were 24.3 °C and 5.3 mg/L, respectively, and median pH was 6.2. Turbidity and Secchi depth were also similar to values from Big Base Lake in that the highest mean turbidity measurement (20.3 NTU) was recorded in the July sample (Fig. 2a) and the shallowest Secchi depth measurement (0.46 m) was recorded in the August sample.

Total nitrogen and total phosphorus concentrations generally increased over the sampling period—the highest concentrations from both lakes were measured on August 20 (Table 2; Fig. 3). Organic nitrogen comprised the majority of the total nitrogen concentration as dissolved ammonia was detected only in the August sample from Big Base Lake and in the July and August samples from Little Base Lake, and nitrite plus nitrate was not detected in any of the three samples from either lake (Table 2). Orthophosphate was detected once on June 4 in Little Base Lake. Total nitrogen to total phosphorus (N:P) concentration ratios declined over time between the June and August samples in both lakes, but the decline was more pronounced in Big Base Lake (Fig. 3). Carlson's TSIs

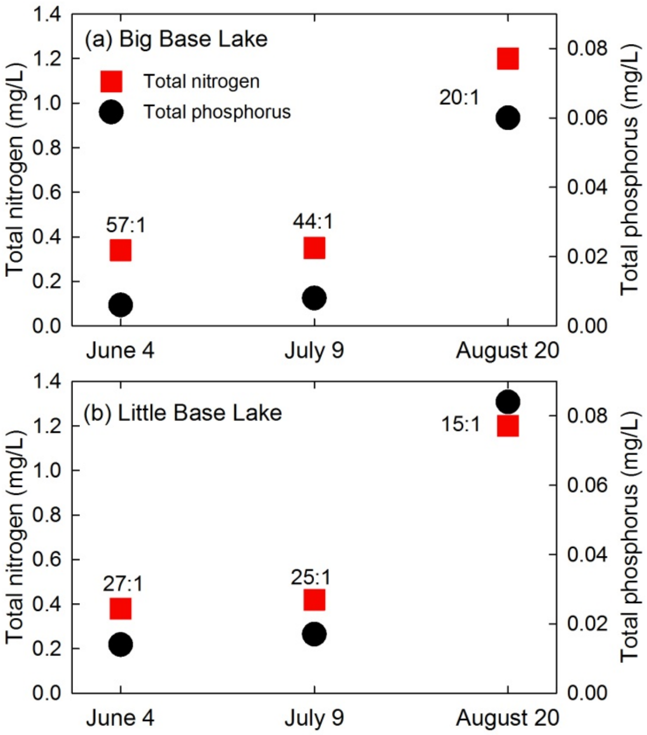

Figure 3. Total nitrogen (N) and total phosphorus (P) for samples collected in June, July, and August for Big Base and Little Base Lakes, Little Rock Air Force Base, Arkansas, 2015. Inset values are N:P ratios. [mg/L, milligrams per liter]

Table 3. Carlson's trophic-state indices of total phosphorus, chlorophyll *a*, and Secchi depth measurements for Big Base and Little Base Lakes, Little Rock Air Force Base, Arkansas, June through August, 2015. Values ≥ 50 (in bold) indicate eutrophic conditions (Carlson 1977).

		Carlson's trophic-state index	
Index	Sample Date	Big Base Lake	Little Base Lake
Phosphorus	June 4	30	42
	July 9	35	45
	Aug. 20	**63**	**68**
Chlorophyll *a*	June 4	**60**	49
	July 9	**69**	**60**
	Aug. 20	**69**	**69**
Secchi transparency	June 4	**59**	**63**
	July 9	**61**	**65**
	Aug. 20	**70**	**71**

for total phosphorus, chlorophyll *a*, and Secchi depth measurements varied from 30 to 70 at Big Base Lake and 42 to 71 at Little Base Lake (Table 3).

In Big Base Lake, total phytoplankton biovolume was highest in the August sample and was second highest in the June sample; however, chlorophyll *a* concentration was lowest on June 4 and highest on July 9 (Fig. 2b-c). The phytoplankton community in Big Base Lake was largely dominated by cyanobacteria over the sampling period (Fig. 4), and taxa within genus *Anabaena* were particularly abundant (Table 4).

In Little Base Lake, total phytoplankton biovolume and chlorophyll *a* concentrations increased over the three sampling events (Fig. 2b-c). However, low total phytoplankton biovolume in the June sample may be underestimated due to a sample-processing error in which the algae sample was poorly preserved. Phytoplankton communities in the June and August samples were predominately cyanobacteria (*Anabaena* spp; Fig. 4; Table 4). In the July sample, cyanobacteria biovolume was relatively low and the overall phytoplankton biovolume was evenly distributed across the four algal groups compared to the biovolume measured in the June and August samples (Fig. 4). The most prominent taxon on July 9 was a colonial diatom, *Tabellaria*; however, a cyanobacterium, *Chroococcus prescotti*, had only slightly less biovolume (Table 4).

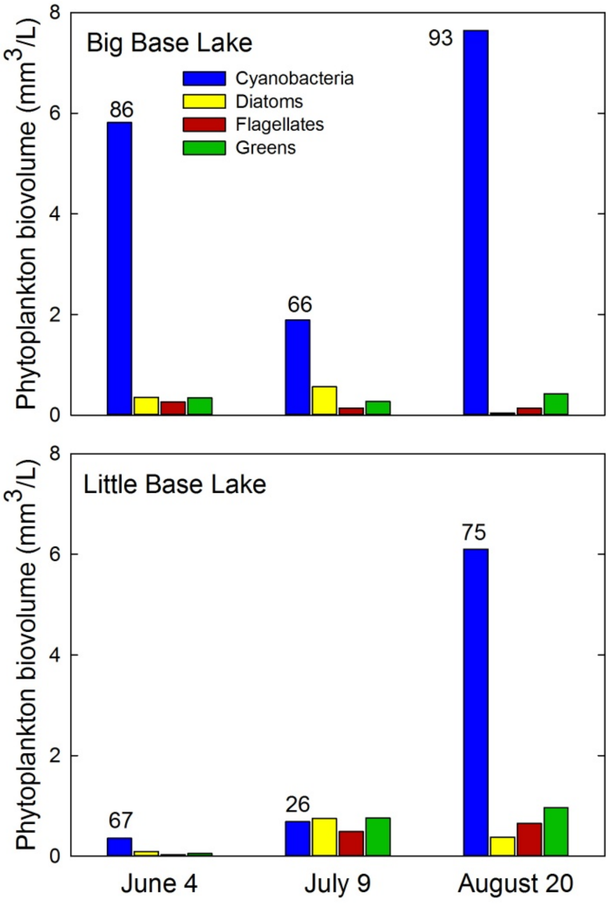

Figure 4. Total biovolume for four groups of phytoplankton in Big Base and Little Base Lakes, Little Rock Air Force Base, Arkansas, June through August, 2015. Inset values are the relative percentages of cyanobacteria. [mm^3/L, millimeters cubed per liter]

Discussion

Nutrient concentrations (including N:P ratios), Carlson's TSI indices, and the large percentage of phytoplankton biomass composed of cyanobacteria indicate eutrophic conditions were prevalent during the three summer sampling events, particularly for the August sample. In general, nutrient-related conditions in Big Base and Little Base Lakes were similar to those observed in the summer conditions in 2003-04 (Justus 2005).

Small temperate lakes and ponds in populated areas are susceptible to pulses of nutrient inputs and eutrophication due to runoff from the landscape, and it is common for lakes to have high, as well as, temporally variable nutrient loads (Dodds and Whiles

Table 4. Synopsis of the three most dominant algae taxa by biovolume collected from Big Base and Little Base Lake, Little Rock Air Force Base, Arkansas, June through August 2015. [mm^3/L, millimeters cubed per liter; %, percent]

Lake	Sample date	Group	Taxon	Biovolume (mm^3/L)	Biovolume (%)
Big Base Lake	June 4	Cyanobacteria	*Anabaena affinis*	4.14	61
		Cyanobacteria	*Anabaena* sp.	1.39	20
		Cyanobacteria	*Anabaena planktonica*	0.24	3
	July 9	Cyanobacteria	*Anabaena planktonica*	1.32	46
		Cyanobacteria	*Gomphosphaeria lacustris*	0.56	19
		Diatom	*Asterionella formosa*	0.55	19
	Aug. 20	Cyanobacteria	*Anabaena planktonica*	5.76	70
		Cyanobacteria	*Anabaena affinis*	1.19	14
		Cyanobacteria	*Anabaena* sp.	0.55	7
Little Base Lake	June 4	Cyanobacteria	*Anabaena affinis*	0.32	61
		Diatom	*Aulacoseria*	0.08	16
		Green	*Pediastrum duplex*	0.04	7
	July 9	Diatom	*Tabellaria*	0.47	17
		Cyanobacteria	*Chroococcus prescotti*	0.4	15
		Green	*Sphaerocystis* sp.	0.3	11
	Aug. 20	Cyanobacteria	*Anabaena planktonica*	4.96	61
		Cyanobacteria	*Anabaena* sp.	0.51	6
		Cyanobacteria	*Anabaena affinis*	0.41	5

2010). Marked increases in total nitrogen and total phosphorus concentrations in the August samples from both lakes could have been partially influenced by precipitation through two different mechanisms. First, heavy rain just prior to the August sampling event likely contributed to an increase in nutrient concentrations in both lakes due to overbank runoff from the surrounding suburban landscape. Second, cool water temperatures near the thermocline on August 20, which is typically hotter than June and July, suggest that precipitation resulted in cooler lake temperatures and subtle mixing of the epilimnion and hypolimnion. This mixing could have exposed the epilimnion to nutrients that had accumulated in the hypolimnion of Big Base Lake over summer. Vertical mixing of the hyplimnion and epilimnion in stratified lakes can release nutrients (e.g. ammonia) from hypoxic sediments (internal load) and alter nutrient concentrations within the water column (Paerl et al. 2001, Wetzel 2001).

Carlson's TSI values for chlorophyll *a* and Secchi depth measurements indicate conditions in both lakes were consistently eutrophic across samples in each month, but phosphorus TSI values indicate that both lakes were mesotrophic during the collection of June 4 and July 9 samples. The highest TSI values as well as increased total phytoplankton biovolume and chlorophyll *a* concentrations on August 20 indicate that these variables generally responded positively to increased nutrients. Carlson's TSI values may vary seasonally as nutrient and phytoplankton dynamics change with differing lake conditions (i.e. temperature, DO, turbidity). Carlson (1977) suggested that chlorophyll *a* be given priority for interpreting trophic status during summer months because the relation between phytoplankton growth and chlorophyll *a* is perhaps more straightforward than the relation between phytoplankton growth and phosphorus.

Phytoplankton communities in both lakes were dominated by cyanobacteria, which composed generally between 66 and 93% of the total phytoplankton biovolume (except for the July 9 sample from Little Base Lake when cyanobacteria biovolume was only 26%; see Fig. 4). Taxa within the genus *Anabaena* were the dominant algae and these species are capable of producing HABs that result in toxins such as microcystin and anatoxin that are harmful to humans and animals (Paerl et al. 2001). Cyanobacteria biovolumes in Big Base and Little Base Lake ranged between 0.24 and 7.5 mm^3/L and represent a low (<2.5 mm^3/L) to moderate risk (2.5-12.5 mm^3/L) to human health based on criteria set by the World Health Organization (WHO) for recreational, non-consumptive waters (Falconer et al. 1999). Biovolumes of *Anabaena* taxa in the current study were generally similar to values reported by Justus (2005); however, the relative proportions of cyanobacteria were considerably higher in the current 2015 study.

The abundance and impacts of cyanobacteria are known to vary with the relative availability of nitrogen and phosphorus in the environment, in which cyanoHABs have often been associated with nutrient enrichment, particularly phosphorus, and lower N:P ratios (Smith 1983, Downing et al. 2001, Paerl et al. 2001, Anderson et al. 2002). Cyanobacteria taxa are able to fix atmospheric nitrogen and may out compete other algae in nitrogen-limited conditions (i.e. low N:P ratios; Smith 1983, Paerl et al. 2001). High biovolumes/proportions of cyanobacteria in the August samples corresponded with increased nutrient concentrations and decreased N:P ratios in both lakes and indicate that both lakes may be vulnerable to periodic cyanoHABs.

Conclusions

Nutrient concentrations and cyanobacteria densities throughout the sample period in Big Base and Little Base Lakes suggest that exposure to additional nutrients, particularly total phosphorus, could result in unfavorable water-quality conditions (i.e. low DO) and increase the risk of toxicity issues associated with eutrophication and cyanoHABs. Based on criteria set by the World Health Organization (WHO) for recreational, non-consumptive waters, densities of cyanobacteria measured during the study pose a low to moderate risk of adverse algal toxicity, and, as such, are a water-quality concern. The occurrence of high proportions of filamentous cyanobacteria in these lakes is an important consideration from a fisheries standpoint, because they are generally considered a poor food source for many aquatic taxa (Paerl et al. 2001). If a large portion of the basal food web is not utilized, increases in nutrient concentrations could further increase the risk of cyanoHABs rather than the more desired effect of increasing fish production, and could decrease the value of these lakes as a recreational resource and as a foraging resource for endangered Interior Least Tern.

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A General Valence-Length Correlation for Determining Bond Orders: Application to Carbon-Carbon and Carbon-Hydrogen Chemical Bonds

F.D. Hardcastle

Department of Physical Sciences, Arkansas Tech University, Russellville, AR 72801

Correspondence: fhardcastle@atu.edu

Running Title: General Valence-Length Correlation for Determining Bond Orders

Abstract

A quantum-mechanical LCAO approach was used to derive Pauling's popular empirical bond valence-length relationship $s = exp((R_o-R)/b)$, where s is the bond order or bond valence associated with bond length R, and R_o and b are fitting parameters. An expression for the b "empirical" fitting parameter is derived in terms of atomic orbital exponents. The b parameters calculated from the atomic orbital exponents are consistent with optimized b parameters. In general, atomic orbital exponents may be used to determine bond valence-length relationships for any chemical bond regardless of valence state, oxidation number, physical or chemical environment.

In this study, almost two-thousand carbon-carbon and carbon-hydrogen bond lengths were evaluated from over 40 compounds to yield reliable bond valence – bond length relationships for C-C and C-H bonds. The atomic orbital exponent for carbon was found to be $\xi_C = 1.651$. Unit valence bond lengths (R_0 where $s = 1$) were found to be 1.493 Å for the carbon-carbon bond and 1.061 Å for the carbon-hydrogen bond.

Introduction

Linus Pauling's principle of electrostatic neutrality (Pauling 1929), or the law of conservation of valence, dictates that the negative charge of each anion in a molecule or crystal is neutralized by the positive charges of neighboring cations and, conversely, that the cationic charges are neutralized by neighboring anions. In application, this is recast as the valence sum rule which states that the sum of the bond strengths (in valence units) around each bonding atom is compensated by the total atomic valence V_i

$$V_i = \sum_j s_{ij} \tag{1}$$

where s_{ij} is the bond valence for each bond to the atom, and V_i is the number of electrons used for bonding (sometimes identical to the oxidation state). The sum of bond valences around any ion, i, is equal to its valence, V_i.

Bond valence – length empirical correlations have been used for many years (Brown and Altermatt 1985; Brown 2002; Brown 2009; Pauling 1947; Zachariasen 1954). In 1947, Linus Pauling presented his empirical bond valence-length expression for carbon-carbon bonds

$$s = \exp\left(\frac{R_o - R}{0.307}\right) = \exp\left(\frac{R_o - R}{b}\right) \tag{2}$$

where s is the bond valence, sometimes referred to as the bond order or bond number – this is also the number of shared electron pairs involved in the bond. R is bond length, R_o sometimes defined as the average bond length and sometimes as the length of a chemical bond having unit valence ($s = 1$), and b is an empirical fitting parameter and sometimes associated with the chemical softness of the bond (Adams 2001). Pauling found that $b = 0.307$ for carbon-carbon bonds (see Eq. (2)), but also successfully used this same equation to describe metal-metal bonding (Pauling 1947).

In practice, b and R_0 are both adjustable parameters found by minimizing the difference between the bond valence sums and the atomic valence of the central bonding atom. Most values of b have been experimentally found to range between 0.25 and 0.65 Å, but because of limited results, b is often assumed to be a universal constant of 0.37 Å which is an average of all tabulated values (Brown and Altermatt 1985). This common assumption changes Eq. (2) to a one-parameter fit and makes it easier to use, but severely limits the applicability of the relationship, decreasing reliability for very short and very long bonds. In fact, there is a large variability in reported b parameters that is sensitive to the selection of R_o as well as crystallographic data. Adams (Adams 2004; Adams 2001) demonstrated that the value of b for a given bond type depends on the arbitrarily chosen maximum bond length, and that the bond valence parameters determined using both the first and second coordination spheres were significantly different from those determined using the first coordination sphere alone.

If the *b* and R_0 parameters have been properly chosen, the combined use of Eqs (1) and (2) have many applications in chemistry. For example, crystal structures may be checked, or the reasonableness of a proposed molecular structure may be evaluated. Another useful application is to determine the total atomic valence (i.e., the number of electrons used in bonding) which is sometimes identical to the oxidation state.

In the present study, the quantum-mechanical LCAO approach is used to derive Pauling's empirical bond valence – length relationship. An expression for the *b* parameter is derived in terms of atomic-orbital exponents. The *b* parameters calculated from the orbital exponents were found to be consistent with bond valence-length data from crystallographic data. This approach was applied to carbon-carbon and carbon-hydrogen bonds by curve-fitting almost two-thousand carbon-carbon and carbon-hydrogen bond lengths collected from crystallographic information files (cif files; Crystallographic Open Database) (Grazulis et al. 2009) from over 40 compounds to yield reliable bond valence – bond length relationships for C-C and C-H bonds.

Theory

Following the widely used method of linear combination of atomic orbitals (LCAO) to represent the bonding between two atoms labeled as 1 and 2,

$$\psi\psi^* = \psi^2 = (\chi_1 + \chi_2)(\chi_1 + \chi_2) = \chi_1^2 + \chi_2^2 + 2\chi_1\chi_2 \tag{3}$$

where ψ is the bonding molecular-orbital wave function, and χ_1 and χ_2 are atomic-orbital wave functions for the bonding atoms, ψ^2 is the probability density distribution function, χ_1 is the wave function for atom 1 and χ_1^2 is its probability density, χ_2 is the wave function for atom 2 and χ_2^2 is its probability density. Once integration over volume space is carried out, the third term ($2\chi_1\chi_2$) becomes the Mulliken population density (Mulliken 1955), or the integrated sum of the overlap between the two atomic-orbital wave functions. This term represents the electronic interaction between the two atoms and is associated with bond strength or bond valence. But prior to integration, the $2\chi_1\chi_2$ term represents the cross-section, or thickness, of the overlap region. For the present purpose, the thickness of the probability density in the overlap region is defined as the "bond order" or "bond valence" or "s." That is,

$$s \equiv 2\chi_1\chi_2 \quad . \tag{4}$$

It is common to use hydrogen-like wave functions to represent a valence electron in a chemical bond. In 1930, Slater (Slater 1930) found that when the wave function of any orbital can be approximated as a single exponential node-less function

$$\chi_{n,l,m} = r^{n-1} e^{-\frac{(Z-\sigma)}{a_0 n^*} r} Y_{l,m}(\theta,\phi) \tag{5}$$

where Z is the nuclear charge of the atom, σ is a screening constant (the core electrons shield the valence electron(s) from the nuclear charge), n^* is the effective principal quantum number, a_0 is the Bohr radius (0.529 Å), and $Y(\theta,\phi)$ is the spherical harmonic term. The pre-exponential factor r^{n-1} scales the function by broadening and shifting as the effective principal quantum number n^* increases.

For the present application, the wave function is "shifted" or "scaled" when the corresponding bond length is normalized to the bond length at unit valence; that is, 2r = R_0 when $s = 1$; this will be done at a later point in the paper. The pre-exponential scaling term r^{n-1} is therefore removed from Slater's wave function, Eq. (5). Since only the radial overlap region between the two bonding atoms is of interest, the spherical harmonic term, $Y(\theta,\phi)$, is also ignored as a constant. The bond order or bond valence (cross section or thickness) between bonding atoms 1 and 2 is now written, starting with Eq. (4), as

$$s = 2\left(c_1 e^{-\xi_1 r_1 / a_0}\right)\left(c_2 e^{-\xi_2 r_2 / a_0}\right) \tag{6}$$

in terms of orbital exponents where, in general, $\xi=(Z-\sigma)/n^*$. Taking the natural logarithm of Eq. (6) gives

$$\ln s = \ln 2 + \ln c_1 + \ln c_2 - \frac{\xi_1 r_1}{a_0} - \frac{\xi_2 r_2}{a_0} \tag{7}$$

The problem here is how to express the two different atomic radii r_1 and r_2 belonging to two unique atoms (and two electrons!) in terms of only one variable, *R*, which is the bond length or interatomic distance between the two different atoms. Clearly, an approximation must be made. In a previous paper (Hardcastle 2013), it was noted that the derivative of the radial distribution function RDF in the overlap region of the chemical bond with respect to *R* yields the maximum which was identified as the atomic radius and the *1/e* distance: $r_1=r_2=R/e$. This led to an erroneous (inconsistent with the data) result for the "*b*" parameter in Eq. (2). In this paper, this disparity will be corrected by using a much simpler approach.

The concept of electronic potential and absolute electronegativity as described by Parr and Pearson (Parr and Pearson 1983) is used in the present study. The absolute electronegativity of Mulliken (in eV) is defined as the average of the ionization potential (I) and the electron affinity (A) (Mulliken 1934). The instantaneous slope of the change in electronic energy with number of electrons, (∂E/∂N), is equal rigorously to the chemical potential μ of the density functional theory, which is the negative of the absolute electronegativity (Parr and Pearson 1983). That is,

$$\chi = -\left(\frac{\partial E}{\partial N}\right)_Z = \left(\frac{I+A}{2}\right) = -\mu \qquad (8)$$

After Parr, the absolute chemical hardness η is defined as

$$2\eta = -\left(\frac{\partial \mu}{\partial N}\right) \qquad (9)$$

which may be recast in a difference form, also using Eq. (8), as

$$\Delta N = \frac{(\chi_1 - \chi_2)}{2(\eta_1 + \eta_2)} \qquad (10)$$

Eq. (10) quantitatively describes the fractional electron transfer from one atom (or molecular species) to another. This relationship shows that electrons will flow from the atom of lower χ (higher potential) to that of higher χ (lower potential) until the electronegativities (or chemical potentials) become equalized. Once the bond is formed, at equilibrium, the (∂E/∂N) curves for both atoms are identical, as indicated by Eq. (8). This means that once a chemical bond is formed, the new radius of either atom 1 or atom 2 is one-half the resulting interatomic distance, *R*/2 (at equilibrium, where both chemical potentials and electronegativities are equal). That is, once the chemical bond is formed, $r_1=r_2=R/2$.

Continuing from Eq. (7), substituting $r_1=r_2=R/2$, and collecting terms, results in

$$\ln s = \ln 2 + \ln c_1 + \ln c_2 - \frac{\xi_1 R}{2a_0} - \frac{\xi_2 R}{2a_0} \qquad (11)$$

For a chemical bond of unit valence, *s*=1 and $R=R_0$ are substituted. Eq. (11) becomes

$$\ln(1) = \ln 2 + \ln c_1 + \ln c_2 - \frac{\xi_1 R_0}{2a_0} - \frac{\xi_2 R_0}{2a_0} \qquad (12)$$

Subtracting Eq. (12) from Eq. (11), simplifying and collecting terms, yields

$$\ln s = \left[\frac{\xi_1}{2a_0} + \frac{\xi_2}{2a_0}\right](R_0 - R) \qquad (13)$$

$$\ln s = \frac{(R_0 - R)}{b} \qquad (14)$$

where,

$$b = \frac{2a_0}{(\xi_1 + \xi_2)} \qquad (15)$$

Eq. (14) is precisely Pauling's empirical bond valence -length relationship, Eq. (2), where the *b* "empirical" fitting parameter is now defined in terms of atomic orbital exponents, Eq. (15). Eq. (15) shows that the *b* parameter may be calculated only from appropriate atomic-orbital exponents ξ_1 and ξ_2 for the two bonding atoms, provided that the atomic orbital exponents are precisely known. Conversely, this also provides a method of determining atomic orbital exponents from experimental bond length data.

Results and Discussion

The *b* and R_0 fitting parameters from the bond length-valence relation, Eq. (2) or Eq. (14), may be found from published crystallographic data, for example from crystallographic information files (cif files). Unreliable XRD data was discarded from the data set only when the results grossly deviated from the known valence of carbon. Using these bond length data, and the conservation of valence formula, Eq. (1), optimized parameters have been found and conveniently compiled into a few major references (Adams 2001; Brown 2002; Brown 2009), as well as on a web site (Adams 2004). A comprehensive list has been tabulated and referenced in a recent publication in this journal (Hardcastle and Laffoon 2012). It is important to recognize that *b* values are closely coupled to the choice of R_o, so that a different (or erroneous) choice of R_0 necessarily affects the value of *b*. Incorrect values of *b* and R_o are noted to result in a correlation that seems to work well for intermediate bond lengths, but not for very long and very short bonds; this observation is common among researchers (Brown 2002). Eq. (15) allows an independent determination of the b parameter, so that the only floating parameter is R_o, defined as the bond length of unit valence for that particular pair of atoms.

The simplest method of calculating an atomic orbital exponent can be traced back to Slater's original work (Slater 1930) where he introduced the node-less single exponential wave function, Eq. (5), and defined the atomic orbital exponent as

$$\xi = \frac{(Z-\sigma)}{n*} \tag{16}$$

where Z is the nuclear charge of the atom, σ is a screening constant, and $n*$ is the effective principal quantum number and a function of n. Slater presented a list of rules (aka, Slater's Rules) for determining the shielding constant σ, the effective quantum number n*, and consequently the orbital exponent ξ, and these rules are routinely included in inorganic chemistry textbooks (Miessler, Fischer, Tarr 2014). More refined values require computation and have been published by many authors including Clementi and coworkers (Clementi and Raimondi 1963; Clementi, Raimondi, Reinhardt 1967), Ghosh and Biswas (Ghosh and Biswas 2002). In this study, it was founds that the atomic orbital exponents found by using the empirically adjusted exchange parameters of Herman (Herman 2004) were more consistent with our curve-fitted results using published diffraction data for elements in the second row of the periodic table (Dodd., Hardcastle, Laffoon 2013).

Carbon-carbon and carbon-hydrogen bond lengths from about 41 carbon compounds were collected as well as almost two-thousand bond lengths from the Crystallographic Open Database (COD). Mercury (version 3.6) free software was used to evaluate the bond lengths from the crystallographic information files (www.ccdc.cam.ac.uk/mercury/). All bond distances up to 4.5 Å were considered in all valence calculations (see Supplemental file). The bond valences were normalized using the valence sum rule, Eq. (1), where carbon uses four electrons for bonding (V_c = 4.000) and hydrogen uses one electron for bonding (V_H = 1.000). This results in the following bond valence-length relationships for C-C and C-H bonds, respectively,

$$s_{C-C} = \exp\left[\frac{(1.493-R)}{0.3205}\right] \tag{17}$$

$$s_{C-H} = \exp\left[\frac{(1.0610-R)}{0.3992}\right] \tag{18}$$

It is a universal practice to assume that the orbital exponent of hydrogen is ξ_H = 1.000 since there is no electron screening and the principal quantum number is assumed to be 1; according to Eq. (16), ξ_H = (Z-s)/n* = (1-0)/1 = 1.000. After a best-fit analysis of all C-C and C-H bond length data, the orbital exponent for carbon was determined to be ξ_C = 1.651. This compares favorably with reported values of 1.5679 (Clementi and Raimondi 1963), 1.625 (Ghosh and Biswas 2002), 1.7210 (2s) and 1.6105 (2p) (Herman 2004). Note that the "*b*" parameter for C-C bonds is 0.3305 in Eq. (17) which is approximately that of 0.307 determined by Pauling in 1947 (see Eq. (2)) in spite of the fact that there was little accurate C-C bond length data available at that time.

To present a few applications showing the usefulness of Eqs (17) and (18), consider the structure of diamond at ambient temperature and pressure (Hom, Kiszenik, Post 1975). The C-C bond lengths in units of Angstroms are 4x1.544, 12x2.52, 12x2.953, 8x4.368 which result in a total carbon valence of 4.02 electrons (or valence units) using Eq. (17). Note that a carbon atom is assumed to form a chemical bond not just to each of its nearest neighbors at 1.544 Å, but to all carbons in the lattice; of course this effect is negligible at distances greater than 4.5 Å. According to valence bond theory, the sp^3 hybridization predicted from the valence bond theory shows the preferred direction of bonding, but not the only direction of C-C bonding in the diamond structure. Another sp^3-hybridized carbon lattice is that of the hexagonal (synthetic) diamond lattice (Bundy and Kasper 1967) which has bond lengths of 3x1.543, 1.545, 6x2.52, 6x2.522, 6x2.956, 6x2.575, 8x3.603 resulting in a total carbon valence of 4.18 electrons.

Consider results from an early structure determination of graphite (Wyckoff 1963) with bond lengths of 3x1.418, 6x2.456, 3x2.836, 2x3.348, 12x3.636, 12x4.152 yielding a total carbon valence of 4.16 electrons. Naphthalene (Fabbiani et al. 2006) shows C-C bond lengths (in Angstroms) of on the C3-labeled carbon as 1.400, 1.423, 1.424, 2.424, 2x2.431, 2.438, 2.796, 2.816, 3.458, 3.520, 3.792, 3.987, 2x4.366, 2x4.671, 4.684, 4.692, 4.702, 4.757, 4.906, and 4.930; applying Eq. (17) yields a total valence of 4.07 electrons for this carbon.

It is also interesting to calculate the C-C and C-H bond valences or bond orders for diatomic species and functionalities. From Eq. (17), C-C bond orders are calculated as follows: C_2^-(doublet), R = 1.2233 Å, s = 2.32 electrons; C_2(singlet), R = 1.24253 Å, s = 2.18 electrons; C_2(triplet), R = 1.3119 Å, s = 1.76 electrons (Huber and Herzberg 1979). Using Eq. (18), the C-H bond order in the diatomic CH doublet can be calculated: R = 1.1019 Å, s = 0.903 electrons.

Conclusions

A quantum-mechanical LCAO approach was used to derive Pauling's empirical bond valence-length relationship. The *b* parameters calculated from the orbital exponents are consistent with optimized *b* parameters calculated from bond valence-length data determined from published crystallographic data.

In this study, almost two-thousand carbon-carbon and carbon-hydrogen bond lengths were evaluated from over 40 compounds to yield reliable bond valence – bond length relationships for C-C and C-H bonds. The atomic orbital exponent for carbon was found to be ξ_C = 1.651 which compares favorably with published values of 1.5679 ((Clementi and Raimondi 1963), 1.625 (Ghosh and Biswas 2002), 1.7210 (2s) and 1.6105 (2p) (Herman 2004). Unit valence bond lengths (R_0 where s = 1) were found to be 1.493 Å for the carbon-carbon bond and 1.061 Å for the carbon-hydrogen bond.

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A Bond Length – Bond Valence Relationship for Carbon – Nitrogen Bonds

C. Harris and F.D. Hardcastle

Department of Physical Sciences, Arkansas Tech University, Russellville, AR 72801

*Correspondence: fhardcastle@atu.edu

Running Title: A Bond Length – Bond Valence Relationship for C-N Bonds

Abstract

In a recent study, Pauling's relationship between bond length and valence was derived along with a definition for his fitting parameter b that incorporates the orbital exponents for each atom contributing to the bond of interest. The values of b for various bonds, including C-N bonds, were calculated using the orbital exponent data. In this study, Pauling's correlation between bond length and bond valence, as well as his valence sum rule, were used with the recently-derived definition for b in order to produce a relationship specifically applicable to C-N bonds. The resulting equation was checked against published x-ray diffraction data for 430 C-N bonds. It is expected, and shown by the data presented in this study, that these equations relating the bond length and bond valence of C-N bonds have sufficient applicability and accuracy for use in any bonding environment, regardless of physical state or oxidation number.

Introduction

The length and valence (strength) of a chemical bond influences the reactivity and structure of the molecule. Consequently, a systematic method of determining bond valence has always been of interest to chemists. In 1929, Linus Pauling (Pauling 1929) published his five rules of chemical bonding which could be used for predicting crystal structures. Pauling's second rule proposes the idea of local charge neutrality, commonly known as the valence sum rule, whereby the charge of an anion is neutralized by the sum of the adjacent cationic charges, while any cationic charge is neutralized by adjacent anionic charges. In terms of bond valence, the total valence at any one atom is equal to the sum of that atom's individual bond valences. In 1947 (Pauling 1947), Pauling published the following bond length-valence relationship:

$$s = \exp\left(\frac{R_O - R}{b}\right) \tag{1}$$

where s is the bond valence, which corresponds to the number of pairs of electrons contributing to the bond, R_o is the length of a chemical bond with unit valence, R is an observed bond length, and b is an empirical fitting parameter. A wide range of determined values for the b parameter, anywhere from 0.25 to 0.65 Å (Hardcastle and Laffoon 2012), led to many inconsistencies in valence values, an issue that hindered the ability of chemists to compare findings. As a result, it was later proposed that a consistent value for b should be established as the average of this range, equaling 0.37 Å as a universal constant for b. This produced a consistent relationship with only one fitting parameter, R_o; however, when applied to shorter and longer bonds, the calculated valence was shown to be less reliable.

Theory

In 2013, Hardcastle derived Pauling's bond length-valence, including a new definition for the b fitting parameter. Since then, a slight modification has been made, resulting in the following equation:

$$b = \frac{2a_o}{(\xi_1 + \xi_2)} \tag{2}$$

where b depends on the Bohr radius of a hydrogen atom, a_o (0.529 Å), and the sum of the atomic orbital exponents for each of the atoms contributing to the bond. This definition produces values for b that are specific to the type of bond being addressed, a more accurate alternative to the average value of 0.37 Å assumed for any type of bond. Combining these values with Eq. (1) produces bond length-valence relationships that vary with bond types, as well.

Methodology

Bond length values were collected for C-N bonds from published x-ray diffraction data totaling 430 C-N bonds. Limiting the data to systems composed of carbon and nitrogen, the total valence at a single carbon or nitrogen atom was calculated by totaling its individual bond valences (see Supplemental). Bond valences were calculated using Eq. (3). Each bond with a length of approximately 4.5 Å or less was included in the calculation. Figure 1 shows the calculated valence of each bond, using Eq. (3), formed by a carbon atom (C1) to carbon and nitrogen atoms in the crystal (Vo et al. 2014).

C1 Environment		Vo 2014	
	Bond Length (Å)	Valence	
C-C Bonds	4.58	5.8458E-05	
	4.243	0.000168955	
	4.58	5.8458E-05	
	4.243	0.000168955	
	3.942	0.000435976	
	1.447	1.127130315	
	3.693	0.000955057	
	4.294	0.000143886	
	3.693	0.000955057	
	4.068	0.000293175	
	4.294	0.000143886	
C-N Bonds	4.072	0.000112852	
	3.565	0.000646944	
	2.363	0.040624071	
	3.565	0.000646944	
	3.388	0.001190195	
	2.363	0.040624071	
	3.771	0.000318228	
	3.388	0.001190195	
	3.771	0.000318228	
	3.731	0.000365232	
	3.561	0.000655918	
	1.139	2.751738002	
	3.561	0.000655918	
	3.867	0.000228636	
	3.867	0.000228636	
	4.17	8.0524E-05	
	4.124	9.43476E-05	
	4.17	8.0524E-05	
	4.124	9.43476E-05	
		3.970405992	Total

Figure 1. The bonding environment for a single carbon atom (C1) showing the bond lengths, calculated bond valences, and the total atomic valence.

Results and Discussion

Data analysis and error minimization relative to the expected atomic valence values led to a specific relationship for C-N bonds:

$$s_{C-N} = \exp\left[\frac{(1.425 - R)}{0.2984}\right] \tag{3}$$

This equation was shown to produce accurate valence values from published bond length data.

In a previous study by Hardcastle and Harris (Harris and Hardcastle 2015), bond relationships were derived and tested for C-C and C-O bonds. However, the approach to calculating total atomic valence for the carbon and oxygen atoms was recently found to be inadequate and a new method was implemented in the present study. Prior to this research, only the shortest few bond lengths were incorporated into the atomic valence calculation, ignoring any intermolecular bonds. The longer bonds between molecules correspond to valence values that can significantly affect the atomic valence of the target carbon or nitrogen, as shown in this study.

The total atom valence for a nitrogen-centered environment was found to be either 3.00 or 4.00 valence units. That is, nitrogen is capable of forming three bonds, or it can use its lone pair of electrons to form a fourth bond. Comparing the calculated atomic valences to the predicted valences, the total error for the C-N bonding was minimized by manipulating R_o, the length of a C-N bond having a bond number or bond order of exactly one. Due to the relative confidence in the orbital exponents, those values were not changed in order to minimize error, but were instead held constant.

The atomic orbital exponent for carbon was found to be $\xi_C = 1.6844$ from a very recent study (Hardcastle 2016) and that for nitrogen was found to be 1.8620 respectively, close to published values (Herman 2004). Substituting these values into Equation (2), results in a *b* parameter of 0.2984 Å for C-N bonds. Note that this value is much lower than the previously assumed universal constant of 0.37 Å set by Brown and Altermatt (Brown and Altermatt 1985). This leaves R_o in Eq. (1) as the only remaining fitting parameter which was found to be $R_o = 1.4250$ Å as the C-N bond length representing unit valence; that is, the ideal C-N single bond.

Conclusion

The bond length – bond valence relationship proposed by Linus Pauling provides a useful tool for the prediction and evaluation of crystal structures when used in tandem with his valence sum rule. Until recently, his equation contained two fitting parameters, *b* and R_o, causing inconsistencies as various *b* values were determined. In the present study, we determined a reliable relationship for finding C-N bond valence from bond length based on using Eq (1) and using Eq. (2) to find the b parameter from atomic orbital exponents, and Ro from the best fit 430 C-N bond lengths. R_o for an ideal C-N bond of unit bond valence (bond order of 1) was found to be $R_o = 1.4250$ Å.

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Early Cementation of the Short Creek Oolite Member, Boone Formation (Osagean, Lower Mississippian), Northern Arkansas

K.A. Jayne[1], A.K. Chandler[2], and W.L. Manger[1]

[1]*Department of Geosciences, University of Arkansas, Fayetteville,* [2]*Arkansas Geological Survey, Little Rock*

Correspondence: wmanger@uark.edu

Running Title: Early Cementation of Short Creek Oolite

Abstract

The Short Creek Oolite is the only formally named member of the Boone Formation in northern Arkansas. It lacks bedding features, and oolith concentrations that would suggest a shoal environment, and it occurs at variable stratigraphic horizons within the upper Boone Formation consistent with episodic deposition as grain-flow slurries. As with modern oolite examples, such as Joulters Cays, Bahamas, the Short Creek preserves numerous intraclasts, and at least one large olistolith indicating an early cementation history.

Introduction

The Short Creek oolite was proposed as a member of the Boone Formation (Osagean, Lower Mississippian) for exposures along the stream of that name heading in Newton County, Kansas, and flowing westward into the Spring River in Cherokee County, Kansas (Smith and Siebenthal 1907). Those authors described the interval as a persistent, massive, homogeneous bed of concentric ooliths that was 20.3-45.7 cm (8-18 in) thick. The unit was identified in a number of sections in southwestern Missouri, particularly quarries in the vicinity of Springfield, Greene County, and Joplin, Newton County, where it thickens to 0.61-2.4 m (2-8 ft) (Spreng 1961). It is the only formally named member of the Boone Formation recognized in Arkansas with only sporadic occurrences, but reaching a maximum thickness of 7.6 m (25 ft) at War Eagle Quarry (Lisle 1983) (Fig. 1).

Deposition of the Short Creek in northern Arkansas is somewhat problematic. The concentration of ooliths is lower than would be expected for a shoal, typically less than 50% of the grain volume (Lisle

Fig. 1. Short Creek Oolite exposed in the abandoned War Eagle Quarry, on the south side of U.S. Highway 412, accessible on a road just east of the bridge over War Eagle Creek between Old Alabam and Harmony, Madison County, Arkansas. Upper Boone exhibits sharp, planar contacts above and below a 7.6 m (25 ft) interval of Short Creek Oolite (white arrows). This locality was studied by Lisle (1983).

1983), while non-oolith grains, mostly crinozoan ossicles and columnals, comprise as much as 25% (Fig. 2). Lime mud matrix and calcite cement may contribute as much as 75% in some intervals (Lisle 1983). Bedding is planar, and there is no obvious evidence of a high energy regime, particularly a lack of exposures with tabular cross-bedding (Fig. 1). Contacts of the oolitic interval with the adjacent upper Boone strata are sharp and the interbedded limestone-chert succession above and below those contacts is identical (Fig. 1). It seems more probable that these ooliths were transported down-ramp as periodic grain-flow slurries derived from shoal areas that probably developed sporadically as Upper Mississippian sea level fell during the Kaskaskia II regression (Witzke and Bunker 1996). There are far more exposures of the upper Boone Formation in Arkansas that have no oolite development compared with those that do contain the member.

Early Cementation History

Rip-up Clasts and Intraclasts

Although apparently unattributed, the term *rip-up clast* is applied to flat, mud clasts that have been stripped by currents from semiconsolidated mud deposits and transported to a new location (Neuendorf et al. 2011). *Intraclasts* were defined by Folk (1959) as a component of limestones, representing torn-up and reworked fragments of poorly cemented, penecontemporaneous sediments deposited within the same basin as their origin. Oolite deposits commonly produce intraclasts because: 1) they are deposited in shallow water and can be exposed either by tidal change, or brief drops in sea level; 2) the original aragonitic composition is easily dissolved and redeposited as cement by rain and interstitial water. Major et al. (1996) reported that some cored intervals taken through the modern oolite shoal developed at Joulters Cays, north end of Andros Island, Bahamas, comprised as much as 30% intraclasts (Fig. 3).

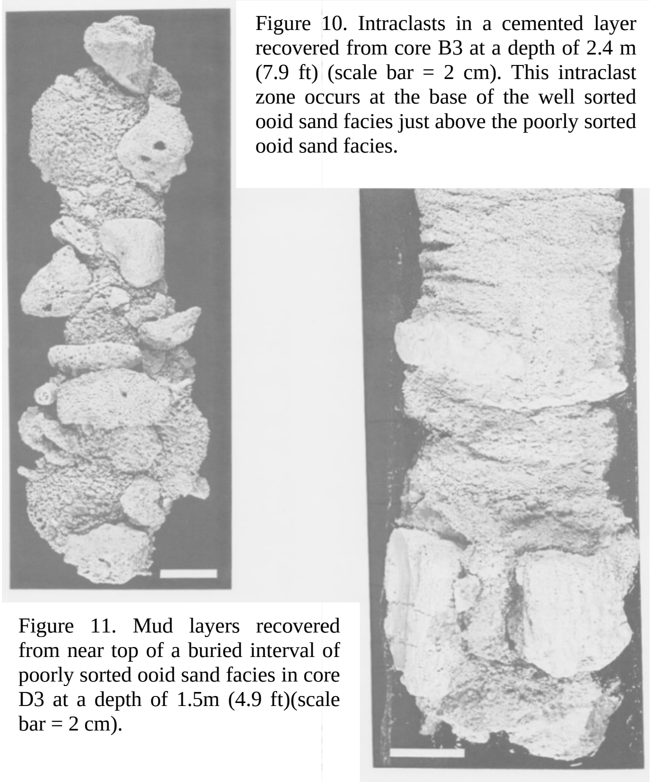

Figure 10. Intraclasts in a cemented layer recovered from core B3 at a depth of 2.4 m (7.9 ft) (scale bar = 2 cm). This intraclast zone occurs at the base of the well sorted ooid sand facies just above the poorly sorted ooid sand facies.

Figure 11. Mud layers recovered from near top of a buried interval of poorly sorted ooid sand facies in core D3 at a depth of 1.5m (4.9 ft)(scale bar = 2 cm).

Fig. 3. Intraclasts and cemented mud layers in poorly sorted oolitic sands, Joulters Cays, Bahamas (Figs 10 & 11 reprinted with permission from Major et al. 1996)

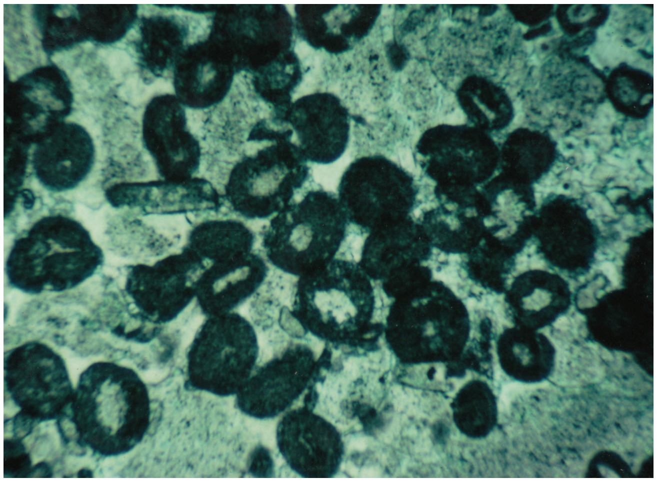

Fig. 2. Photomicrograph of Short Creek Oolite from War Eagle Locality. Clouded grains are crinozoan ossicles and columnals; light areas are calcite spar.

Many exposures of the Short Creek Oolite encountered across the northern Arkansas outcrop belt contain intraclasts similar to those reported by Major et al. (1996) (Fig. 4).

Olistoliths

Flores (1955) proposed the term *olistolith* for large exotic blocks transported by submarine gravity sliding or slumping within the host deposit. Braden and Ausbrooks (2003) described a massive oolite block at least 23 m. (76 ft) long and nearly 4.6 m. (15 ft) high encased within the Short Creek Oolite (Fig. 5). The juxta-position of a large block of well-cemented oolite preserved as an olistolith within a similar oolitic interval is further confirmation of the susceptibility of this lithology to early cementation**.**

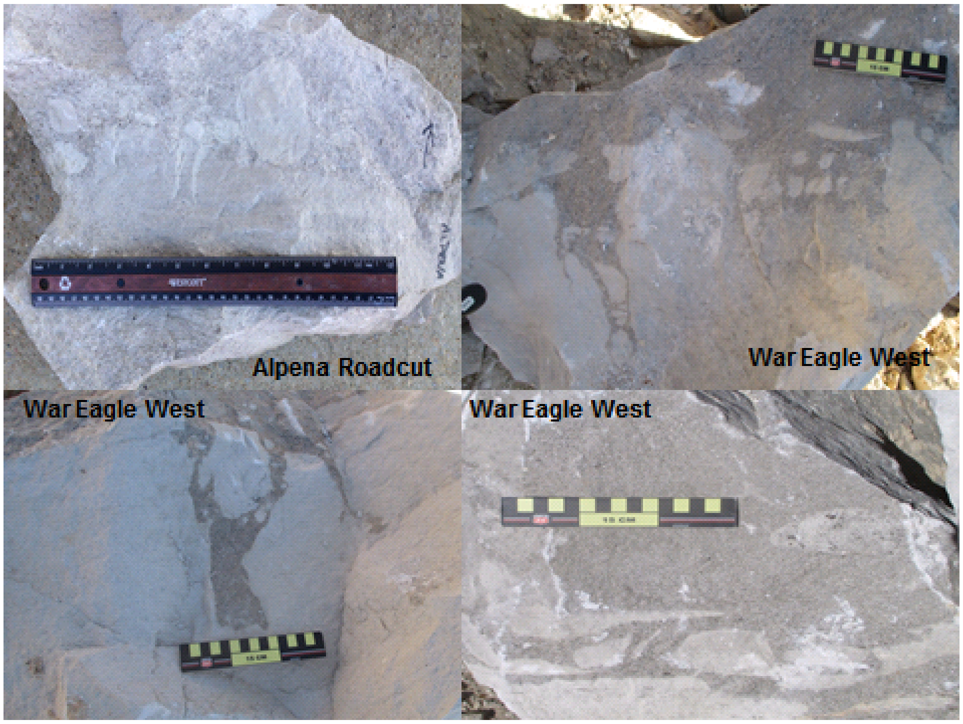

Fig. 4. Intraclasts of Short Creek Oolite incorporated into a matrix of Short Creek Oolite; Alpena Roadcut - Ark 412 just west of Alpena, Carroll County; War Eagle West - temporary quarry operation, now abandoned, on north side of Ark 412, west of junction with Ark 23 (principal scale divisions in centimeters).

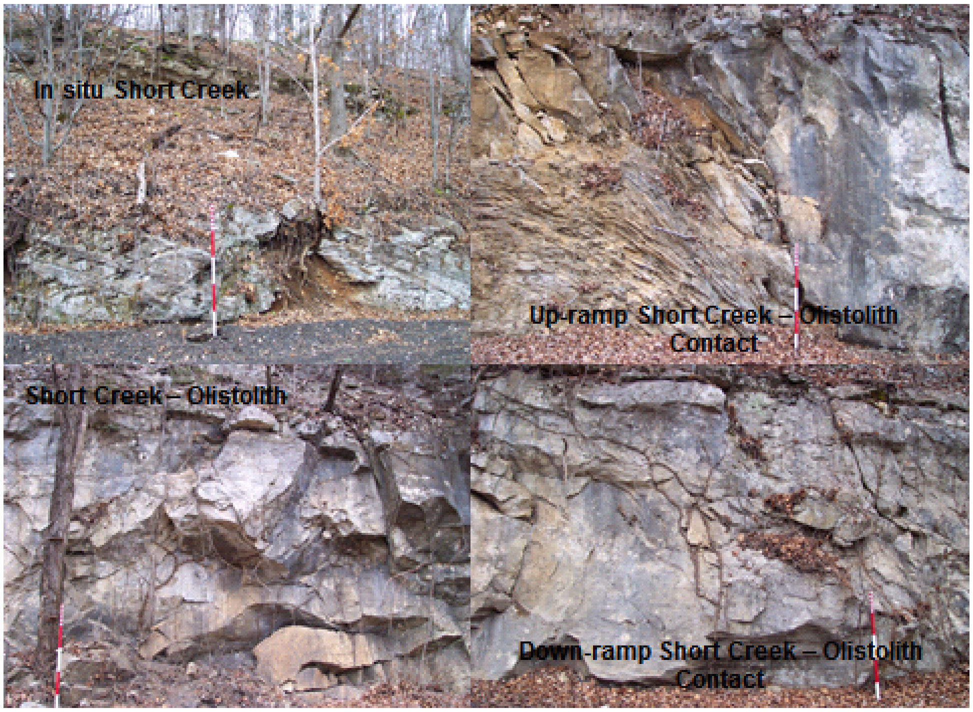

Fig. 5. Views of the Short Creek Olistolith in the Parthenon Quadrangle, Newton County, Arkansas (Braden and Ausbrooks, 2003) (scale divisions in feet).

Conclusions

Intraclasts are common in the modern oolite shoal environment on Joulters Cay, Bahamas. There, solution of carbonate by meteoric water is reprecipitated as cement lithifying surface crusts during periodic exposure of the oolite. These crusts are broken, transported and concentrated in low areas on the shoal by periodic storms, after which they become buried by continued formation of unconsolidated oolite. The Short Creek does not exhibit typical oolite shoal features, such as tabular cross-bedding, but the same process effecting Joulters Cay likely occurred during Short Creek deposition, producing intraclasts that could be transported and redeposited by grain-flow slurries. Cementation of large areas produced blocks - olistoliths - that were moved down-slope, perhaps by early shelf instability reflecting local fault movements, and became buried by unconsolidated oolite transported there also by grain-flow slurries.

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Impacts of Man-Made Structures on Avian Community Metrics in 4 State Parks in Northwestern Arkansas

R.D. Keith[1]*, B. Grooms[2], and R.E. Urbanek[3]

[1]*Department of Biological Sciences, Arkansas Tech University, Russellville, AR 72801*
[2]*Department of Biological Sciences, Arkansas Tech University, Russellville, AR 72801*
[3]*Department of Environmental Studies, University of North Carolina Wilmington, Wilmington, NC 28403*

*Correspondence: rkeith3@atu.edu

Running Title: Impacts of Man-Made Structures on Avian Community Metrics

Abstract

Avian community metrics often differ between areas with no human disturbance and areas with high levels of human disturbance. However, the relationships between avian community metrics and smaller-scale disturbances are not as clear. Our goal was to investigate if avian abundance, richness, evenness, and diversity differed in areas with and without small-scale human developments. We used fixed-radius 50-m avian point counts to compare points which contained a man-made structure (n = 47), such as a picnic area, road, or campsite to those that did not contain a man-made structure (n = 181) at 4 state parks in Arkansas during 18 May – 7 August 2015. We used paired t-tests to compare points at the park scale and one-way ANOVAs or Kruskal-Wallis tests to investigate differences among the hiking and biking trails within parks. At the park scale, avian abundance (t_3 = -1.44, P = 0.246), richness (t_3 = -0.86, P = 0.453), diversity (t_3= 2.02, P = 0.137), and evenness (t_3 = -0.37, P = 0.733) did not differ between points containing man-made structures and points without man-made structures. Species richness ($F_{1,11}$ = 5.03, P = 0.047) and diversity (χ^2_1= 4.20, P = 0.040) were higher at points with man-made structures (Simpson's D mean = 0.13 ± 0.01SE; S mean = 8.99 ± 0.70SE) at Pinnacle Mountain than points without man-made structures (Simpson's D mean = 0.18 ± 0.03SE; S mean = 7.17 ± 0.47SE); abundance ($F_{1,11}$ = 1.43, P = 0.257) and evenness ($F_{1,11}$ = 0.16, P = 0.695) did not differ among points. Within the 3 remaining parks, abundance ($F_{1,7\text{-}9}$ = 0.11 – 2.59, P = 0.152 – 0.748), richness (χ^2_1 = 0.300 – 1.68, P = 0.195 – 0.584), diversity (χ^2 = 0.300 – 1.05, P = 0.305 – 0.584; $F_{1,7}$ = 1.82, P = 0.219) and evenness ($F_{1,7\text{-}9}$ = 0.35 – 4.28, P = 0.077 – 0.570) did not differ between points with and without man-made structures. Given the results of our analyses both at the park scale and within parks, it appears that small-scale man-made disturbances may have limited or no impact on avian community metrics.

Introduction

Human interference can impact avian abundance, assemblages, diversity, and species evenness (Burger 1981, McGarigal and McComb 1995, Trzcinski et al. 1999, Crooks et al. 2004, La Sorte and Boecklen 2005, Brown 2007, Ferenc et al. 2014). Non-consumptive use of natural resources, such as hiking, biking, and birdwatching, has been shown to reduce avian reproductive success (Miller et al. 1998, Kangas et al. 2010), increase predation on avifauna (Desgranges and Reed 1981), and have overall negative impacts on bird communities (Askins et al. 1990, Knight and Gutzwiller 1995). Urban development also tends to have negative impacts on avian community dynamics, with larger urban areas having decreased diversity, lower species richness, and lower species evenness when compared to more rural areas (Burger 1981, Friesen et al. 1995, Aurora et al. 2009, Crooks et al. 2004, Ferenc et al. 2014, Verma and Murmu 2015). As with urbanization, forest fragmentation can also have negative impacts on avian community metrics, with fragmented forests having less diversity, lower species richness, and lower avian abundance than continuous forests (Brown 2007). However, other studies have found that fragmentation has negligible impacts on avian abundance, and that habitat loss, even on a small scale, is a more important contributing factor to reductions in species richness and abundance (McGarigal and McComb 1995, Trzcinski et al. 1999).

Although large scale fragmentation such as creation of urban and suburban developments has a clear influence on abundance and species composition of avifauna, smaller scale disturbances in natural areas may have less obvious, yet still important, impacts. It has been demonstrated that in locations where human visitation is high, avian survivorship may be lowered, particularly during migration (Burger 1981), thus reducing overall avian abundance in these areas. Human visitation can result in bird avoidance of high-traffic areas and in turn can lower abundance during migration and nesting periods on sites where man-made structures, such as trails, are present (Burger 1981, Gutzwiller et al. 1998, Kangas et al. 2010). Non-consumptive human use of trails and recreational areas can also disturb avian communities and disrupt both feeding and breeding behaviors, particularly among ground-dwelling species (Gutzwiller et al. 1998, Aben et al. 2008, Kangas et al. 2010, Thompson 2015). A study conducted in central Texas focusing on the relationship between golden-cheeked warblers (*Dendroica chrysoparia*) and mountain biking activity showed that warbler territories where mountain biking was present were smaller, and nest success was reduced when compared to sites where mountain biking was not present (Davis et al. 2010). As a result of reduced nesting success, abundance of this species may have been reduced, meaning that man-made biking trails and the associated activity has the capacity to damage populations of individual avian species. Studies in forested settings have also shown that, similar to biking trails, roads have the potential to negatively impact avian abundance and species richness, not only due to increased vehicle traffic, but also due to increased foot traffic along roadways (Polak et al. 2013).

While edge habitat creates areas that allow a variety of species with different habitat requirements to converge, this does not mean that avian communities will be positively affected by edge that is created by man-made structures and openings. Increased predation and human interaction can decrease species abundance, richness, diversity, and evenness (Weatherhead et al. 2010, Cox et al. 2012), but variations in the magnitude of predation and human activity along human-induced edges may impact the degree of change that is observed within avian community metrics. Given that some studies have found that human recreational activities in natural settings have either negative effects or no effect on avian community metrics (Banks and Bryant 2007, Aben et al. 2008, Davis et al. 2010, Kangas et al. 2010, Polak et al. 2013, Wolf et al. 2013, DeLuca and King 2014), we hypothesized that increased human activity may negate the positive effects of increased edge at sites with man-made structures, particularly those that see frequent use. Therefore, we predicted that we would observe a reduction in species richness, diversity, and abundance at points with a man-made structure compared to points with no man-made structure. Although many studies have not investigated species evenness, we predicted that a lower species diversity would also lead to a lower overall evenness, in accordance with Friezen et al. (1995) and Kluza et al. (2000).

Materials and Methods

Four state parks located in close proximity to the Arkansas River in central and west-central Arkansas served as the focus for our study: Mount Magazine State Park, Petit Jean State Park, Mount Nebo State Park, and Pinnacle Mountain State Park. Mount Magazine, Petit Jean, and Mount Nebo are located in the Arkansas River Valley ecoregion, while Pinnacle Mountain is located in the Ouachita Mountain ecoregion (USEPA 2016). Mount Magazine State Park is located in Logan County, south of Paris, AR (15 S 442199, 3895222). The park encompasses 904ha surrounded by the Ozark National Forest and includes Arkansas' highest point in elevation, Mount Magazine (839m). The park is located on top of the mountain, a flat topped plateau rimmed by sandstone bluffs which supports a diverse collection of wildlife and vegetation species adapted to the mountain ecosystem. The park is composed of 8 trails with a combined length of 22.5km and offers 13 cabins and 18 campsites for visitors. Average yearly precipitation for the park is 137cm with the average yearly temperature being approximately 13 ^{o}C (NOAA 2015).

Mount Nebo State Park is located in Yell County, west of Dardanelle, AR (15 S 476945, 3897552). The park encompasses 1,246ha and is centered on Mount Nebo which measures 411m in elevation. The park habitat is mostly comprised of thick oak (*Quercus* spp.) and hickory (*Carya* spp.) dominated forests, characteristic of the Ozark Plateau region, with mixes of sweetgum *(Liquidambar styraciflua)* and red maple (*Q. rubra*) stands throughout the park. The park is composed of 6 trails with a combined length of 22.5km and offers 15 cabins and 44 campsites. Average yearly precipitation for the area is 123cm with average yearly temperatures ranging from 10^{o}C (low) to 23^{o}C (high) (NOAA 2015).

Petit Jean State Park is located in Conway County, west of Oppelo, AR (15 S 505957, 3886563). Petit Jean Mountain, measuring 367.89m, lies between the Ozark and Ouachita mountain ranges in the Arkansas River Valley and serves as the midpoint for the 1,416 ha Park. Habitat of the park is composed mostly of forests dominated by a mix of oak, hickory, and pine (*Pinus* spp.) stands within a series of ponds, streams, and glades, characteristic of the Ozark mountain ecoregion (Keith 1987, Arkansas Forestry Commission 2010). The park offers 8 trails with a combined length of 37km and offers 33 cabins and 125 campsites to visitors. Average precipitation for the area is 127cm with average temperatures ranging from -1^{o}C (low) to 34^{o}C (high) (NOAA 2015).

Pinnacle Mountain State Park is located in Pulaski County, Northwest of Little Rock, AR (15 S 547062, 3855665). The park encompasses 809ha centered on Pinnacle Mountain (308m) covering a mosaic of habitats including boulder fields, bald cypress (*Taxodium distichum*) swamps, bottomland hardwood forests, and upland forests composed of mixes of oak, hickory, and pine stands. As a result of the varying habitat types, the park's Arboretum that maintains woody vegetation from across the state, and the 2 rivers that run through the park, the park supports a diverse variety of avian species. Pinnacle Mountain offers 10 trails with a combined length of 30km and offers no camping to visitors. Average yearly precipitation for the park is 127cm with the average temperature being 18^{o}C (NOAA 2015).

Sampling of avifaunal community metrics occurred from 18 May – 7 August 2015. Parks were visited in 1-week increments (Monday- Friday), rotating among the 4 parks so that each park was sampled 3 times during the study. We chose trails within each park based on length, habitat type diversity, and total area of the park that they encompassed. Trails measuring <16km in length were included in the study, with trails 8 – 16km split into 2 equal portions to accommodate temporal limitations of accessing them. Trails fitting the distance criteria above were further categorized by choosing trails that passed through the greatest diversity of habitat types (Arkansas Forestry Commission 2010) and that encompassed the greatest area of park use. We observed these attributes by plotting the trails on a map overlay in ArcGIS (Environmental Systems Research Institute, Inc., Redlands, CA) to discern what habitat areas the trails passed through and by assessing the total coverage of the trail in the park. Applying these criteria to the trails in each park resulted in 7 trails at Mount Nebo State Park, 6 trails at Mount Magazine State Park, 6 trails at Petit Jean State Park, and 8 trails at Pinnacle Mountain State Park to be included in the study. Initial sampling of avian point locations at each state park were located at randomly selected points within 250m of the each major trail's trailhead. We identified subsequent sampling locations systematically at 250m intervals in order to ensure independence of bird count data.

Avian point counts began within a period of 15 minutes before sunrise each weekday and lasted until 4 hours after sunrise (~05:45–10:00hr). We conducted point counts only during suitable weather conditions for avian activity which were defined as: mornings with no rain or fog (although temperate, light drizzle can be tolerated by most species; Cyr et al. 1995, Martin et al. 1997), and wind speeds <13km/hr (Freedmark and Rogers 1995, Petit et al. 1995).

Each point was sampled independently 3 times per week, once each by 3 observers. This methodology resulted in 9 visits per all 228 points (i.e., 3 times per week at each point during 3 independent weeks), with 45 minutes of total observation time collected per point. By utilizing 3 observers throughout the week rather than 1, as is common in many avian surveys, we were able to diminish repeated observer bias and also increase the detection probability at each point. Points along each trail were visited at random times so that no point was visited at the same time throughout the week by any of the 3 observers. Birds sighted/heard at each study point were identified to species level, recorded by their 4 letter alpha codes (Pyle and Desante 2003), and specified in their location relative to the study point, their distance from the study point, and if the spotting was visual or auditory via symbols established by Ralph et al. (1993). Additionally, the presence of man-made campsites, picnic areas, cabins, houses, roads, and other structures within the 50m plot was recorded by 1 observer per point.

Once sampling was complete, we calculated the average community metric values for points containing a man-made structure and points without a man-made structure at each state park. We calculated average abundance (N) for each point by dividing the number of individual birds counted over the 3 observers. By using the average instead of the total number of birds observed, we accounted for the probability that each individual bird was counted 3 times in 1 week, once by each observer. We calculated species richness (S) by totaling the number of species observed by the 3 observers at each point to ensure that all species observed at each point were taken into account. Lastly, using data from all observers at each point, we calculated Simpson's Evenness Index (E) and Simpson's Diversity Index (D). Using the state parks as replicates (n = 4), we used a paired t-test ($\alpha = 0.05$ for all analyses; SAS/STAT software Version 9.3) to determine if avian community metrics differed between points with man-made structures and points without man-made structures. After we analyzed the data at the park level, we analyzed data using one-way ANOVAs or Kruskal-Wallis tests to investigate differences using the trails within each park as replicates.

Results

In total, we located 47 man-made structures across the 4 state parks. Of these structures, approximately 41% were roads, 17% were small homes or cabins, 9% were parking lots, 7% were campgrounds, 6% each were bridges, power line structures, and small sheds or storage buildings, and 4% each were picnic areas/benches, and miscellaneous small concrete structures. At the park scale, neither avian abundance ($t_3 = -1.44$, $P = 0.246$), richness ($t_3 = -0.86$, $P = 0.453$), diversity ($t_3 = 2.02$, $P = 0.137$), nor evenness ($t_3 = -0.37$, $P = 0.733$) differed between points containing man-made structures and those without man-made structures (Table 1).

Subsequent analyses within the 4 parks largely failed to reveal differences in avian community metrics at points with and points without a man-made structure, with the only differences occurring at Pinnacle Mountain. Within that park, we observed 9 total man-made structures at our 53 points, consisting of 33% powerline structures, 22% roads, and 11% each of bridges, parking lots, picnic areas, and small concrete structures. Species richness ($F_{1,11} = 5.03$, $P = 0.047$) and diversity ($\chi^2_1 = 4.20$, P = 0.040) were higher at points with man-made structures than points without man-made structures; abundance ($F_{1,11} = 1.43$, P = 0.257) and evenness ($F_{1,11} = 0.16$, P = 0.695) did not differ among points at Pinnacle Mountain (Figure 1).

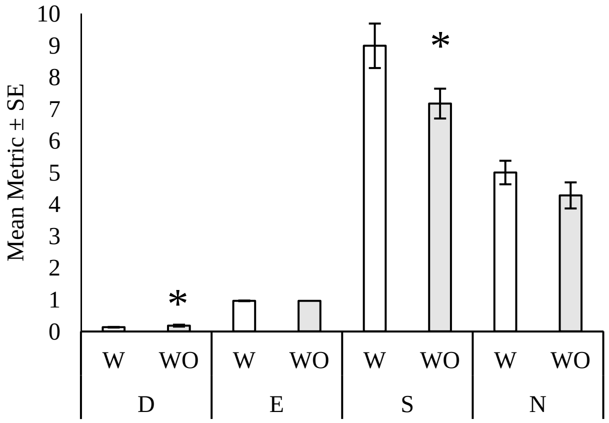

Figure 1. Comparison of mean (±SE) avian Simpson's Diversity (D), Simpson's Evenness (E), species richness (S), and abundance (N) at points with (W) and without (WO) a man-made structure at Pinnacle Mountain State Park, Arkansas, 2015. Asterisks indicate significance at $P = 0.05$.

At Mount Magazine, 12 total structures were located within our 60 points, and consisted of 67% roads, 17% parking lots, 8% campgrounds, and 8% small sheds or storage buildings. Avian abundance ($F_{1,9} = 0.11$, $P = 0.748$), richness ($\chi^2_1 = 0.300$, $P = 0.584$), diversity ($\chi^2_1 = 0.300$, $P = 0.584$), and evenness ($F_{1,9} = 0.76$, $P = 0.407$) did not differ among points with and without man-made structures (Figure 2).

Table 1. Comparison of mean (±SE) avian Simpson's Diversity (D), Simpson's Evenness (E), species richness (S), and abundance (N) at points with (W) and without (WO) a man-made structure at 4 state parks in Northwestern Arkansas, 2015. There were no differences between points for any metrics (*paired* $t_3 = -0.86 – 2.02$ $P = 0.137 – 0.733$).

Park	D	E	S	N
Pinnacle				
W	0.12±0.01	0.96±0.01	5.19±0.44	9.22±0.74
WO	0.19±0.02	0.97±0.01	3.86±0.41	6.86±0.62
Magazine				
W	0.19±0.01	0.90±0.01	4.98±0.51	6.61±0.54
WO	0.22±0.02	0.88±0.02	4.88±0.54	5.83±0.47
Petit Jean				
W	0.16±0.02	0.92±0.01	5.07±0.38	8.03±0.65
WO	0.20±0.03	0.95±0.02	3.64±0.44	6.61±0.77
Nebo				
W	0.18±0.02	0.96±0.00	3.86±0.28	6.84±0.47
WO	0.17±0.01	0.93±0.01	4.79±0.31	7.62±0.44

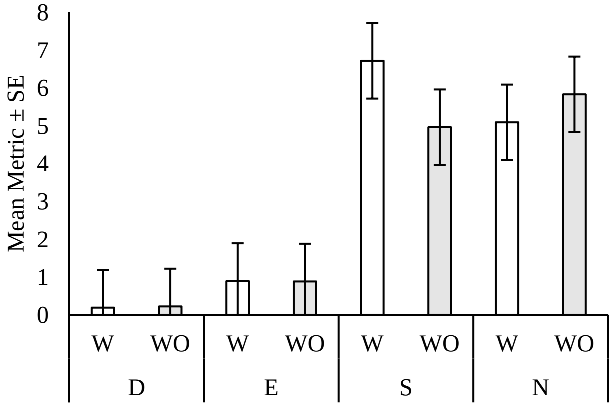

Figure 2. Comparison of mean (±SE) avian Simpson's Diversity (D), Simpson's Evenness (E), species richness (S), and abundance (N) at points with (W) and without (WO) a man-made structure at Mount Magazine State Park, Arkansas, 2015. There were no differences between points for any metrics ($\chi^2_1 = 0.300$, $P = 0.584$; $F_{1,9} = 0.11 – 0.76$, $P = 0.407 – 0.748$).

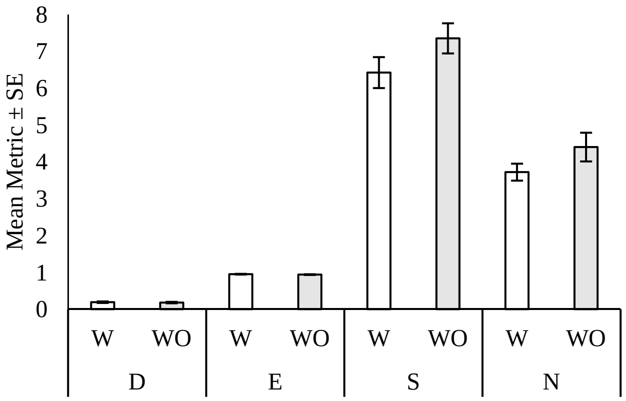

Figure 3. Comparison of mean (±SE) avian Simpson's Diversity (D), Simpson's Evenness (E), species richness (S), and abundance (N) at points with (W) and without (WO) a man-made structure at Mount Nebo State Park, Arkansas, 2015. There were no differences between points for any metrics (χ^2_1 = 1.052 – 1.581, P = 0.209 – 0.305; $F_{1,8}$ = 0.35 – 1.12, P = 0.321 – 0.570).

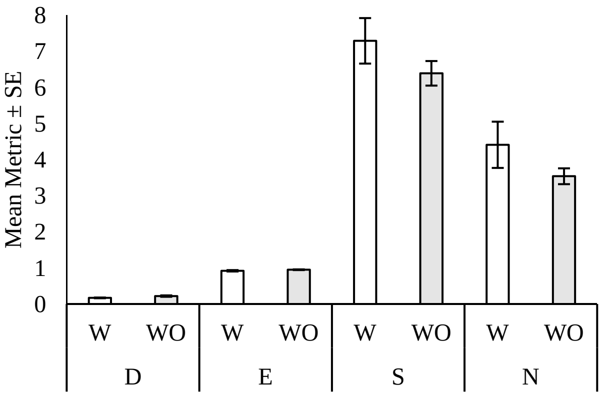

Figure 4. Comparison of mean (±SE) avian Simpson's Diversity (D), Simpson's Evenness (E), species richness (S), and abundance (N) at points with (W) and without (WO) a man-made structure at Petit Jean State Park, Arkansas, 2015. There were no differences between points for any metrics (χ^2_1 = 1.681, P = 0.195; $F_{1,7}$ = 1.82 – 4.28, P = 0.077 – 0.219).

At Mount Nebo, we located 15 structures at our 56 total points, consisting of 53% small homes or cabins, 13% sheds or other utility buildings, 13% campgrounds, and 7% each of parking lots, roads, and picnic areas. Similar to Mount Magazine, abundance ($F_{1,8}$ = 1.12, P = 0.321), richness (χ^2_1 = 1.581, P = 0.209), diversity (χ^2_1= 1.052, P = 0.305), and evenness ($F_{1,8}$ = 0.35, P = 0.570) also did not differ among points at Mount Nebo State Park (Figure 3).

At Petit Jean State Park, 11 total structures were located within our 59 total points, 73% of which were roads, 18% of which were bridges, and 9% of which were other structures, such as small sheds or storage buildings. At Petit Jean we also found no difference in abundance ($F_{1,7}$ = 2.59, P = 0.152), richness (χ^2_1 = 1.681, P = 0.195), diversity ($F_{1,7}$ = 1.82, P = 0.219), or evenness ($F_{1,7}$ = 4.28, P = 0.077) among points with and without man-made structures (Figure 4).

Discussion

Both among parks and within parks at the trail level, we found either no difference or minimal difference in avian community metrics among points with man-made structures and points without man-made structures. These results are somewhat expected given that several studies focusing on the relationship between small scale human development and avian community metrics have found little difference when comparing forested areas without trails and human recreational activity to those where trails, small structures, and human activity were present (Gutzwiller et al. 1994, DeLuca and King 2014, Thompson 2015). One possible mechanism for this lack of differences is the size of the structures themselves. The largest structures within our 50-m plots were small houses, cabins, and powerline structures while studies that have found differences in avian community metrics generally investigated effects of larger structures and urbanized areas (Friesen et al. 1995, Hudson et al. 1997, Ferenc et al. 2014). Because structures in our study were small, the disturbances that they created may not have been large enough to affect avian community composition. Although dividing our structures into categories based on size or type would have been beneficial, given that we had relatively few structures at our study points overall (n =47), subdividing them further in order to perform further analyses would have likely not yielded meaningful results. For example, if we were to logically divide man-made structures into "small", "medium", and "large" categories at each of the 4 parks, we would have very few structures representing each of those categories. As such, the small sample sizes would negate our ability to detect any effects between treatments. Also, the dividing line between each category would be arbitrary, as what constitutes a "small" or "large" structure would be somewhat open for interpretation. Therefore, even if there was a statistical difference in one or more community metric(s) at medium vs. large structures, for example, the difference may have only been caused by our arbitrary categorization rather than by actual differences in the avian communities at the different sizes of structures.

Another potential explanation for overall lack of differences in community metrics is the proximity of the structures in our study to a trail. Because each survey point in our study was centered on a trail, the effects of openings created by trails may have reduced the impacts of structures on avian community metrics. Canopy openings created by trails may have changed avian community metrics when compared to areas of the forest with no trails, which our study did not include. Because recreational trails have been shown to affect avian community metrics and avian behavior (Gutzwiller et al. 1998, Miller et al. 1998, Banks and Bryant 2007, Wolf et al. 2013, Thompson 2015), a study comparing points containing structures and points without structures where no points were located on or near trails could yield results different from our study. However, because human-made structures generally have a road or trail leading to them, it may be difficult to locate enough structures that are independent of trails that could be utilized in a study.

The trails themselves may also be a factor that influenced our findings because human activity is much higher in these areas due to non-consumptive use (e.g., biking, jogging, and hiking) than areas without trails. High levels of human activity can deter birds from areas that may otherwise be occupied and has been shown to cause changes in avian community metrics, particularly abundance (Desgranges and Reed 1981, Knight and Gutzwiller 1995, Gutzwiller et al. 1994, Miller et al. 1998, Davis et al. 2010, Kangas et al. 2010, Thompson 2015). Because trails and human use disrupt avian communities, it is possible that the presence of trails negatively impacted our ability to detect differences between points with and without structures.

A final potential explanation for the lack of differences in avian community metrics within our study points is that the majority of species that we detected were either mid-story or canopy dwelling. Several studies have shown that birds that nest or forage on the forest floor show greater responses to human recreational activity than those that forage or nest farther from the ground (Banks and Bryant 2007, Wolf et al. 2013, Thompson 2015). If understory-foraging or understory-nesting birds would have comprised a greater proportion of birds observed in our study, it is possible that our results would have shown differences in community metrics at points with versus points without a man-made structure. The ability to classify species into different guilds was a shortcoming in our study, compared to previous studies (Gutzwiller et al. 1998, Banks and Bryant 2007, Kangas et al. 2010, Thompson 2015). It is likely that avian guilds are affected differently by human activity and man-made structures (Thompson 2015), therefore running separate analyses for ground-dwelling and canopy-dwelling birds, for example, may have yielded different results in terms of the 4 community metrics in which we were interested. However, given that avian representatives from some guilds, particularly ground-dwelling species, were uncommon at our study sites, and given that our study was focused on the avian community as a whole, we feel that the manner in which we analyzed our data was appropriate.

Given that the influence of human activity can have a significant impact over avian community metrics, it would have also been beneficial to account for the amount of recreational usage that each individual man-made structure received. However, given the time available to us and the scope of the project, we were not able to perform the surveys and monitoring necessary to obtain this data. Another issue with this type of analysis would have been the time that some of the structures were used. Campsites, for instance, may have been in use by park visitors 24 hours per day, while some structures, such as the powerline clearcuts, may have not seen any use by park visitors whatsoever.

Pinnacle Mountain avian community metrics were unlike the other parks in this study; both avian species richness and species diversity were higher at points with man-made structures. There are several characteristics of Pinnacle Mountain that may have caused these differences. One explanation for the differences in richness and diversity at Pinnacle Mountain may lie in the structures themselves. At the other 3 parks in our study, the majority of structures consisted of roads, small cabins, and small homes. At Pinnacle Mountain, however, many of the structures that we observed were either powerline clearcuts, parking areas, or were structures directly adjacent to parking areas such as picnic tables. Powerline structures and the large associated clearcuts were a unique feature to Pinnacle Mountain among the 4 parks. The powerline structures themselves were still small enough in size to be included in our study; however, the clearcuts maintained beneath these powerlines were fairly large and continuous, with maintained strips extending throughout the park and out of the park boundaries. These clearcuts, which were located within 3 of our study points at Pinnacle, consisted of early successional vegetation and herbaceous grassland species which may have attracted a different suite of species not seen throughout the more forested sections of the park. Therefore, powerline structures and clearcuts may have created an edge effect with the surrounding forest, resulting in a larger number of species and a higher diversity of species in plots containing one of these structures. An unfortunate shortcoming of our overall study was that no other parks contained powerline clearings or comparable types of clearings that would have allowed us to analyze the impacts of these types of structures further, therefore we can only speculate that these powerline structures were a factor in our findings that points at Pinnacle Mountain containing structures had a higher avian richness and diversity than points not containing structures. Our results suggest that further studies focusing specifically on powerline clearcuts and associated structures would be pertinent.

Due to the Pinnacle Mountain's proximity to Little Rock, AR, visitation at this park is high and parking areas and picnic areas are frequently used by humans. Although this might be expected to have negative effects on community metrics, we observed that human refuse, such as leftover food, concentrated a number of avian species in these areas, which may have contributed to higher diversity and species richness at Pinnacle. Although it is difficult to say for certain why avian richness and diversity were higher at points with structures compared to without structures at Pinnacle Mountain but not at other parks we visited, type of structure and levels of human activity are likely causes.

Another shortcoming of our study was that we did not calculate detection probability. Although we increased detection probability by visiting each park on 3 separate occasions and employing 3 independent observers, it is still not possible to detect all individuals at all point count locations. As we did not account for detection probability in our community metric estimates, we may have introduced a bias in more densely populated areas, possibly causing us to underestimate certain avian metrics, such as abundance and species diversity (Farnsworth et al. 2002, Thompson 2015). It has also been suggested that vegetation density may influence the probability of detection of songbirds (Richards 1981). Although vegetation density may decrease along man-made structures and trails (Loss and Blair 2011, Thompson 2015), DeLuca and King (2014) reported that this does not appear to alter the probability of detecting songbirds visually or aurally. Therefore, we feel justified in not accounting for changes in vegetation when taking detection probability into consideration.

Management Implications

Gaining knowledge about the impacts of man-made structures and campsites in natural areas and the ways in which they affect wildlife is important when considering future construction and placement of such structures. For example, we found that small campsites and other structures generally had no impact on overall avian community composition; however, groups of structures such as neighborhoods or larger individual structures that were not observed in our study sites may have meaningful effects on bird communities. Therefore, further studies that focus on larger structures could be important in deciding whether construction of such sites within state parks could be detrimental to avian communities. Although our study indicated that human structures largely had no effect on avian communities in state parks, it may be beneficial to perform similar studies with different taxa of wildlife. For example, amphibians, which tend to have smaller home ranges when compared to birds (Bellis 1965, Watson et al. 2003, Fellers et al. 2013), may be more greatly affected by small-scale disturbances.

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DNA Barcoding of the First Recorded American Burying Beetle, *Nicrophorus americanus*, in Clark County, Arkansas

J. Kelly*, T. Files, B. Baley and N. Reyna

Department of Biology, Ouachita Baptist University, 410 Ouachita Street, Box 3792, Arkadelphia, AR 71998-0001

Correspondence: Kellyj@obu.edu

Running Title: DNA Barcoding of the American Burying Beetle, *N. americanus,* in Clark County, AR

Abstract

The American Burying Beetle (ABB), *Nicrophorus americanus*, is a red-listed endangered species under the Endangered Species Act (16 U.S.C. 1531 *et seq.).* We serendipitously recorded 3 individuals of this species during a forensic study in the summer of 2013. These specimens represent the first known records for Clark County, AR and the southeastern-most record in the State since the extirpation of the species from the region in the late 1800's. Two males and one female were collected, photographed, sexed and measured. One male specimen was deceased upon discovery. The remaining two individuals were released. The U.S. Fish and Wildlife Service (USFWS) was notified of the accidental catch and death of an endangered species as required and the specimen was awarded to Ouachita Baptist University for further study. The deceased specimen was used for DNA barcode sequence analysis. A 400bp section of the cytochrome *c* oxidase I (COI) gene was amplified using gene specific primers and then sequenced using Sanger sequencing methods. Sequence analysis revealed the collected beetle to be 98.5% identical to the ABB voucher sequence and was 86% similar to other *Nicrophorus* species. Taken together the DNA sequence analysis results and taxonomic identification both support the identification of our specimen.

Introduction

We discovered three specimens of the American Burying Beetle (ABB), *Nicrophorus americanus* during a forensic study in the summer of 2013 in Clark County, Arkansas. Two males and one female were discovered on experimental pig and rat carrion over a three night period. Burying beetles are commonly associated with carrion (Scott 1998). A male specimen was found deceased on the second night and we realized it was an endangered ABB species. We immediately made contact with the United States Fish and Wildlife Service (USFWS) to report the accidental capture of an endangered species outside of its' known range. That specimen would be awarded to Ouachita Baptist University by letter from an Endangered Species specialist. Two subsequent individuals were noted in the next evening sample which were measured, sexed and released. Those captures were also reported. We suspended the field collections at that point to avoid the capture of further endangered ABB after consulting with the USFWS. Our specimens were captured in a mature growth forest just east of the City of Arkadelphia, AR. This location is consistent with the known preference of habitat as stated in Lomolino and Creighton (1996) and (Sikes 2005).

Reports of ABB capture are sporadically received by the USFWS but most tend to be inaccurate within the genus based on common field identification errors. Other closely related *Nicrophorus* species captured in our 2013 study included *N. orbicolis* and *N. tomentosus*. Our accidental capture report was met with initial skepticism until detailed descriptions and a crude phone camera photo were submitted (Figure 1). ABB are readily identifiable by their bright orange to red coloration on the head and pronotum, a feature lacking in the other *Nicrophorus* species (Sikes and Peck, 2000). ABB are also typically much larger than their closely related species and are the largest of the Silphid beetles in North America (Anderson and Peck 1985). The biology and distribution of the ABB is well established into four ecoregions within the United States, including the northwest region within the State of Arkansas (USFWS 2008).

A few previous studies have examined the genetic variation of the ABB in Arkansas (Kozol et al. 1994) and (Szalanski et al. 2000) and we knew that genetic comparisons were available for the ABB in the iPlant DNA Subway (Goff et al. 2011). We decided to confirm the identity of our specimen using DNA barcoding methods to eliminate any consideration of a false identification in the field. This was risky due to us

Figure 1. Deceased American Burying Beetle male on rat carrion in a bucket trap in Clark County, AR.

having only one individual to work with so we decided to run a test study with the closely related Nearctic burying beetle, *Nicrophorus orbicolis*. This study demonstrated that DNA extraction was best achieved using the material near the joints of the legs of the beetle. Our DNA barcoding effort was designed based upon the results of that study (Kelly and Jackson, unpub).

Materials and Methods

DNA extraction, PCR and Sequencing

DNA extraction and PCR were conducted using the DNA Barcode Amplification Kit (Carolina Biological Inc. Cat# 211385) without modifications. This kit was specially designed to be a robust DNA extraction procedure and was made under the recommendations of the International Barcode of Life project and the iPlant Collaborative Bar Code Project (Goff et al. 2011). A single beetle leg was used for DNA extraction. PCR was done using the Animal/Insect primer mix (Carolina Biological Cat# 211513). This primer mix is a cocktail of primers that target a 650 base pair segment of the mitochondrial cytochrome c oxidase subunit 1 (COI) gene. The insect specific primers LepF1A (5'-ATTCAACCAATCATAAAGATATTGG-3') and LepR1 (5'TAAACTTCTGGATGTCCAAAAAATCA-3') are included in this cocktail (Herbert et al. 2004). Both primers contained the M13 (5'-GTAAAACGACGGCCAGT-3') sequence on their 5' end. M13 specific primers were used for DNA sequencing. PCR amplicon purification and single direction sequencing were performed by GENEWIZ, inc. This sequence was submitted to NCBI GenBank (Accession ID: KX687862).

Sequence Analysis and Alignment

Sequence chromatograms were edited and assembled using the iPlant: DNA subway editing tool (http://dnasubway.iplantcollaborative.org/, Goff et al. 2011). These alignments were examined by eye to detect potential base calling errors, particularly at the beginning and ends of traces. Potential errors were checked in the trace files and corrected (shortened) as necessary. Figure 1 provides the shortened trace file submitted for comparison. Sequence alignments and similarity were generated using MUSCLE [v. 3.8.31], (Robert, 2004) as implemented by DNA Subway. Additional, alignments, comparisons and dot plot were generated directly using the Basic Local Alignment Search Tool [BLAST 2.3.1] (Altschul et al. 1997) on the NCBI website (http://blast.ncbi.nlm.nih.gov/Blast.cgi). Our BLAST results were compared to the *Nicrophorus americanus* voucher specimen.

Results and Discussion

DNA Barcode Analysis

DNA barcoding uses a 650 base pair region of DNA associated with the mitochondrial cytochrome oxidase subunit 1 gene (COI) to create a genetic DNA barcode (Ratnasingham and Herbert 2013, Sikes and Venables 2013). Identification is achieved by comparing the sequenced data or genetic barcode to a reference library containing known taxa or voucher sequences (Ratnasingham and Herbert 2007).

A 600 base pair region of the Clark County ABB specimen was isolated and sequenced using conventional DNA barcode protocols (Goff et al. 2011). However this sequence was trimmed to a 352 base pair section (Figure 2) which was used for analysis and identification. Trimming was performed due to several misreads at the ends of each tail of the ABB sequence. While there was reliable data with good homology in these areas the occasional presence of misread basses, designated with an n, would potentially make this data un-reliable. We did not feel confident in including misreads in our submission.

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>TTATTTTATTTTTGGTGCCTGAGCAGGAATAGCCGGGATATCACTTAGAATATTAATCCGAGTAGAGTTA
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AGCCCCTGATATAGCTTTCCCTCGATTAAATAATATAAGATTTTGATTATTACCCCCATCATTATCATTG
TTATTAATCTCTAGAATAGTAGAAAGAGGAGCTGGCACAGGTTGAACAGTGTACCCCCCACTCTCAGCCA
ATATTGCTCATAGAGGATCTTCTGTAGATTTAGCAATTTTTAGATTACATTTAGCTGGTATTTCGTCAAT
TCTTGGAGCAGTAAATTTTATTACAACAGTAATTAATATACGATCACCAGGGATAACCTTTGATCGAATA
CCATTATTTGTATGATCAGTTGCTATTACTGCTTTATTACTCCTTTTATCTTTACCTGTACTAGCAGGAG
CTATTACTATATTACTTACAGATCGAAATTTAAATACATCCTTTTTTGATCCCGC
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Figure 2. FASTA trimmed data for the Clark County 2013 American Burying Beetle specimen (GenBank ID: KX687862).

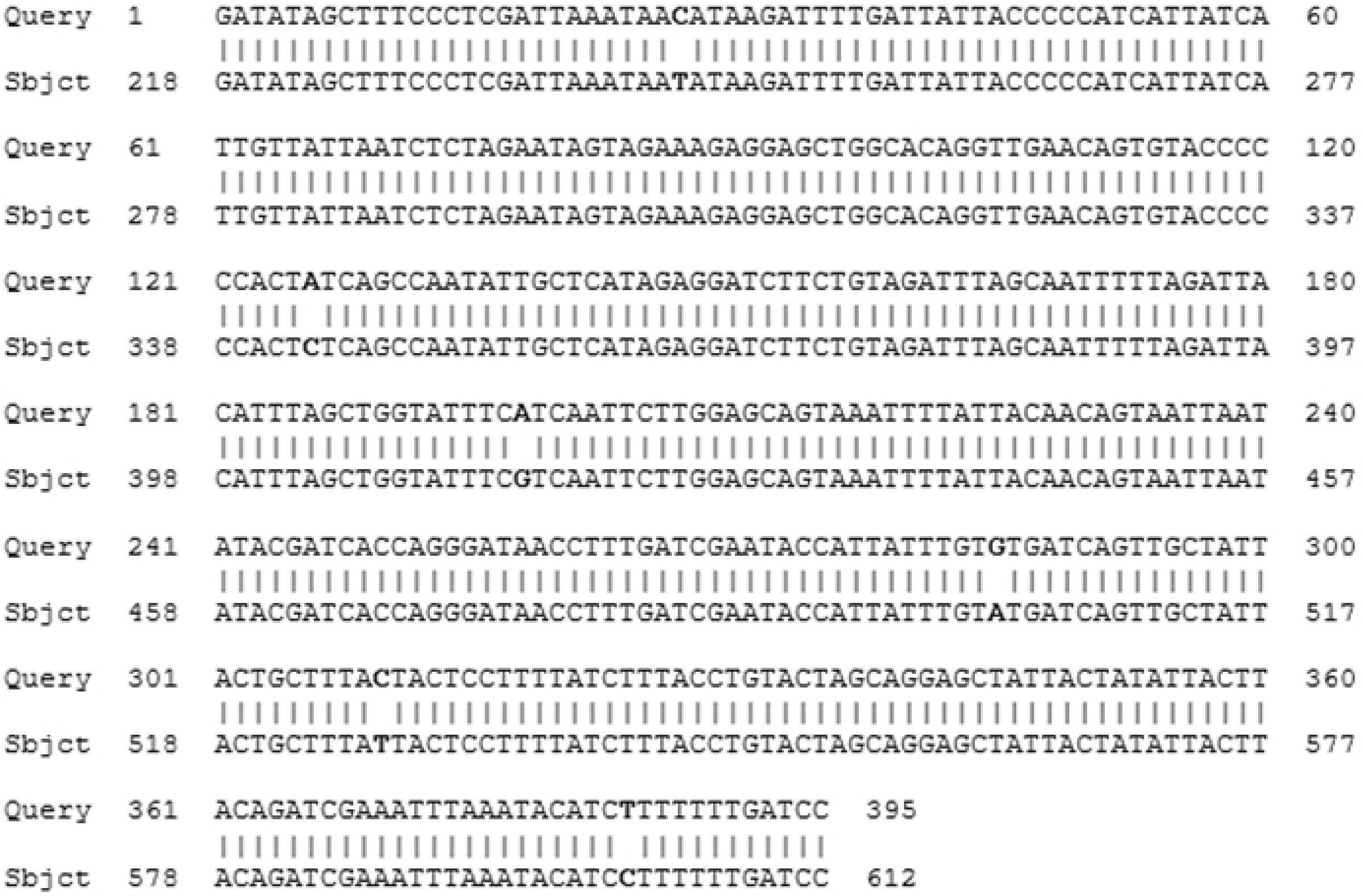
However, it should be noted that misreads are common at the beginning and ends of DNA sequenced with Sanger sequencing methods. Due to the scarcity of our material, we were unable to submit additional samples for sequencing.

BLAST analysis revealed this sequence (GenBank ID: KX687862) to be 98.6% identical to the American Burying Beetle voucher sequence (GenBank ID: EU147412) (Figure 3).

It should be noted that the gene bank voucher sequence was submitted as the entire COI gene and is over 2,000 base pairs long, however only the first 400 base pairs of this gene are commonly used for DNA barcode analyses (Ratnasingham and Herbert 2013, Sikes and Venables 2013). Interestingly, other submitted *Nicrophorus* species COI voucher sequences have been trimmed to only include the COI gene. This may be due to the endangered status of the ABB. No other *Nicrophorus* species has a sequence similarity above 87% when compared to our sequence (Figure 4).

Conclusions

The aim of this study was to confirm that we had discovered and properly identified three specimens of the endangered American Burying beetle, *Nicrophorus americanus* in Clark County, AR in the summer of 2013. Based upon the strong physical characteristics used during the 2013 field and lab identification of the Clark County specimens and the strong COI DNA sequence correlation between our specimen and the gene bank voucher specimen, we conclude that the three individuals captured in Clark County in 2013 were the endangered American Burying Beetle, *Nicrophorus americanus*. DNA barcoding is an effective tool which assists in species identification and reduces potential errors related to taxonomic impediment. The USFWS has indicated that further regional sampling will take place in 2015 to detect any persisting Clark County ABB populations. Further studies by Ouachita Baptist University biologists have



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Query  1    GATATAGCTTTCCCTCGATTAAATAACATAAGATTTTGATTATTACCCCCATCATTATCA  60
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Sbjct  218  GATATAGCTTTCCCTCGATTAAATAATATAAGATTTTGATTATTACCCCCATCATTATCA  277

Query  61   TTGTTATTAATCTCTAGAATAGTAGAAAGAGGAGCTGGCACAGGTTGAACAGTGTACCCC  120
            ||||||||||||||||||||||||||||||||||||||||||||||||||||||||||||
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Query  121  CCACTATCAGCCAATATTGCTCATAGAGGATCTTCTGTAGATTTAGCAATTTTTAGATTA  180
            ||||| ||||||||||||||||||||||||||||||||||||||||||||||||||||||
Sbjct  338  CCACTCTCAGCCAATATTGCTCATAGAGGATCTTCTGTAGATTTAGCAATTTTTAGATTA  397

Query  181  CATTTAGCTGGTATTTCATCAATTCTTGGAGCAGTAAATTTTATTACAACAGTAATTAAT  240
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Sbjct  398  CATTTAGCTGGTATTTCGTCAATTCTTGGAGCAGTAAATTTTATTACAACAGTAATTAAT  457

Query  241  ATACGATCACCAGGGATAACCTTTGATCGAATACCATTATTTGTGTGATCAGTTGCTATT  300
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Query  301  ACTGCTTTACTACTCCTTTTATCTTTACCTGTACTAGCAGGAGCTATTACTATATTACTT  360
            ||||||||| ||||||||||||||||||||||||||||||||||||||||||||||||||
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Query  361  ACAGATCGAAATTTAAATACATCTTTTTTTGATCC  395
            ||||||||||||||||||||||| |||||||||||
Sbjct  578  ACAGATCGAAATTTAAATACATCCTTTTTTGATCC  612
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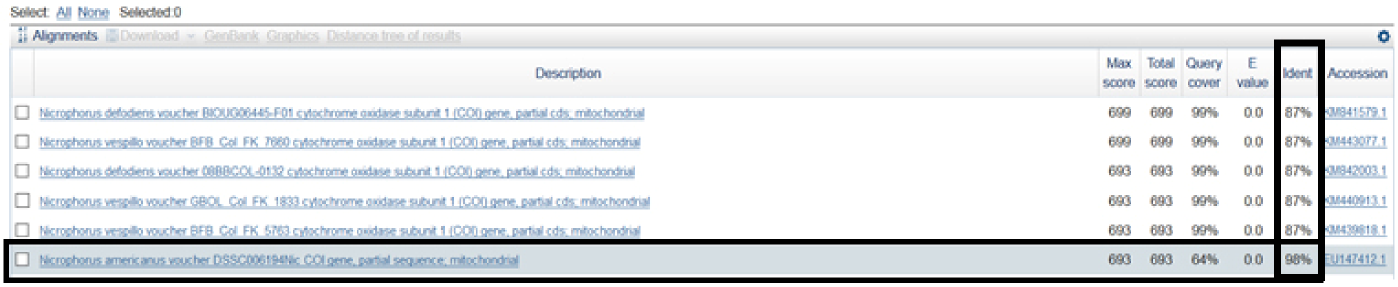
Figure 3. Sequence alignment with the Clark County ABB specimen and the gene bank ABB voucher specimen (EU147412). A 352 base pair sequence alignment of the Clark County and voucher ABB sequences is shown. Alignments were performed using BLAST. Analysis shows a 98.6% similarity between the two specimen sequences. Differences in sequence are noted in bold.



Select: All None Selected:0

Alignments Download GenBank Graphics Distance tree of results

	Description	Max score	Total score	Query cover	E value	Ident	Accession
☐	Nicrophorus defodiens voucher BIOUG06445-F01 cytochrome oxidase subunit 1 (COI) gene, partial cds; mitochondrial	699	699	99%	0.0	87%	KM841579.1
☐	Nicrophorus vespillo voucher BFB_Col_FK_7860 cytochrome oxidase subunit 1 (COI) gene, partial cds; mitochondrial	699	699	99%	0.0	87%	KM443077.1
☐	Nicrophorus defodiens voucher 08BBCOL-0132 cytochrome oxidase subunit 1 (COI) gene, partial cds; mitochondrial	693	693	99%	0.0	87%	KM842003.1
☐	Nicrophorus vespillo voucher GBOL_Col_FK_1833 cytochrome oxidase subunit 1 (COI) gene, partial cds; mitochondrial	693	693	99%	0.0	87%	KM440913.1
☐	Nicrophorus vespillo voucher BFB_Col_FK_5763 cytochrome oxidase subunit 1 (COI) gene, partial cds; mitochondrial	693	693	99%	0.0	87%	KM439818.1
☐	Nicrophorus americanus voucher DSSC006194Nic COI gene, partial sequence; mitochondrial	693	693	64%	0.0	98%	EU147412.1

Figure 4. BLAST result using the Clark County ABB sequence as the query. Analysis reveals a 98% similarity with the ABB voucher sequence (highlighted). Further, the Clark County ABB sample reveals an 87% sequence similarity with other *Nicrophorus* species, supporting the membership of the Clark County specimen within the genus.

been postponed pending a response to an outstanding 2014 endangered species permit request.

Acknowledgements

The authors wish to thank Ouachita Baptist University alumni Jennifer Jackson for her work in the laboratory during a related test study. We are grateful to the U.S. Fish and Wildlife Service Arkansas Field Office for their support and provision of the ABB specimen after reporting. We also acknowledge Dr. J.D. Patterson for funding the 2013 study during which the ABB specimens were found.

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Sequence Stratigraphy of the St. Joe and Boone Formations, Lower Mississippian (Kinderhookian-Osagean), Southern Ozark Region

S.C. Kincade

Department of Geosciences, University of Arkansas, Fayetteville, AR 72701

Correspondence: sck002@uark.edu

Running Title: Sequence Stratigraphy of the St. Joe and Boone Formations

Abstract

The Lower Mississippian (Kinderhookian-Osagean) St. Joe and succeeding Boone Formations are well exposed in northwestern Arkansas, southern Missouri, and northeastern Oklahoma, forming the Springfield Plateau of the southern Ozark region. This interval represents a single, third order, transgressive-regressive eustatic cycle deposited broadly across the North American craton. The initial transgression during the Kinderhookian covered the regional erosional surface developed on either the Devonian-Lower Mississippian Chattanooga Shale, or older units with crinoidal packstones deposited as platform successions or transported as down-ramp slurries. The Boone Formation is divided informally into lower and upper divisions that reflect differences in eustatic sea level. The lower Boone (early Osagean) is composed primarily of calcisiltites with interbedded dark, nodular, penecontemporaneous chert deposited below effective wave base during the maximum flooding interval of the third-order eustatic cycle. The upper Boone (late Osagean-early Meramecian?) represents the third-order highstand, and regressive sequences comprising crinoidal grainstones and packstones, mostly deposited within effective wave base. In contrast to the lower Boone, the upper Boone carbonates are interbedded with white to light gray, later diagenetic chert, the product of groundwater replacement. The formally named Short Creek Oolite Member of the upper Boone Formation is only sporadically developed, probably transported as down-ramp slurries across the region during regression. Across the Springfield Plateau, the Boone Formation is separated by a type I sequence unconformably from succeeding strata of Meramecian or younger age.

Introduction

Lower Mississippian (Kinderhookian-Osagean) strata exposed in Arkansas, Missouri, and Oklahoma are predominately limestones, including packstones, grainstones, calcisiltites, and associated chert, both penecontemporaneous and later diagenetic. The sequence stratigraphy of these strata comprises a third order eustatic cycle that is bounded at the base and top by regional unconformities (Manger and Shelby, 2000). The Lower Mississippian strata are recognized as the St. Joe Formation, which represents the transgressive systems tract (TST), and the Boone Formation, which represents the maximum flooding interval (MFI), highstand systems tract (HST) and a regressive systems tract (RST) of that third order cycle (Manger and Shelby 2000). Understanding the order in which these strata were emplaced is important because it provides insight into the geologic history of Arkansas and surrounding areas, the chert development within the Boone, and the potential for oil and gas plays.

Geologic Setting

The southern Ozark region of northern Arkansas occupies the south flank of the Ozark Dome. The dome is an asymmetrical uplift centered in southeastern Missouri exposing a core of Precambrian granite and rhyolite in the St. Francois Mountains (Manger et al., 1988) (Fig. 1). There are three plateau surfaces that increase in elevation as a result of the Ozark Dome uplift (Fig. 1). The oldest of the three, the Salem Plateau, is underlain mostly by Lower Ordovician limestones and dolomites, with associated orthoquartzitic sandstones. The Springfield Plateau comprises the Lower Mississippian St. Joe Limestone and succeeding chert-bearing limestone of the Boone Formation. The youngest of the three plateaus is the Boston Mountain Plateau, which is located farthest south of the Ozark Dome center. It consists of unconformity-bounded intervals of sandstones, shales, and some limestones representing the Chesterian, Lower Morrowan, Upper Morrowan, and Atokan Series (Manger et al., 1988). Structurally, there are numerous, closely spaced, parallel to subparallel, northeast-southwest, and subordinate east-west trending normal faults across the region.

During the Osagean, a carbonate platform developed, commonly called the Burlington Shelf (Lane 1978), located across most of present day Missouri and eastern Kansas. This shelf produced abundant crinozoan detritus and carbonate mud within effective wave base that was transported down ramp as slurries in a lobate manner that covered most of northwestern Arkansas, northeastern Oklahoma, and southwestern Missouri (Manger and Shelby 2000).

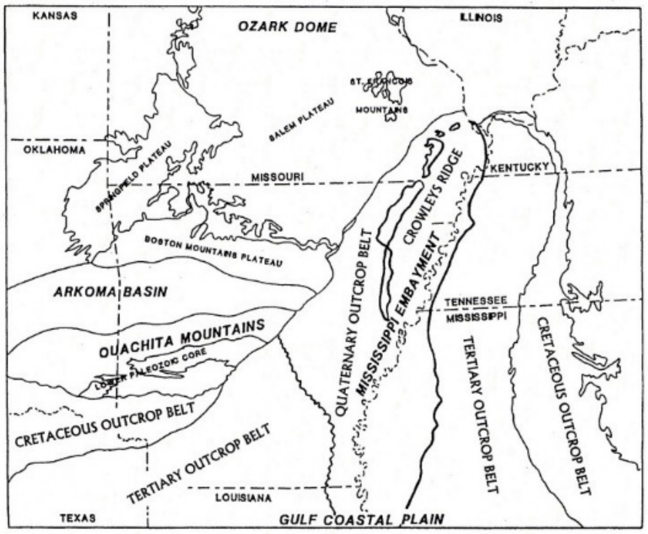

Fig. 1. Geologic Provinces of Arkansas and Adjacent Areas, Southern Midcontinent (modified from Manger et al. 1988).

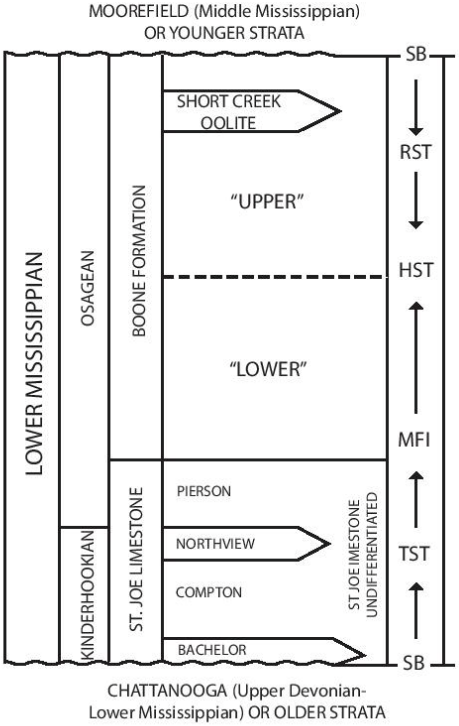

Fig. 2. Lower Mississippian Lithostratigraphy- Southwestern Arkansas (modified from Manger and Shelby 2000).

Lithostratigraphy

The transgressive-regressive sequence of the Lower Mississippian comprises the St. Joe (Hopkins 1893), and the succeeding Boone Formations (Branner 1891, Simonds 1891) of northwest Arkansas (Fig. 2). The St. Joe Formation consists of crinoidal packstones and carbonate mudstones that were deposited as down ramp slurries coming from the Burlington Shelf. In northwestern Arkansas, the St. Joe Formation is subdivided into four members (in ascending order): the Bachelor, Compton, Northview, and Pierson (Manger and Shelby 2000). The Bachelor Member sits uncomformably as a green calcareous shale atop the Chattanooga Shale (Upper Devonian). However, when the Bachelor overlies formations as old as Middle Ordovician, it is an orthoquartzitic sandstone. The Northview Member is a calcareous siltstone separating the underlying Compton and overlying Pierson Members, both crinozoan packstones (Fig. 3). It should be noted that in Missouri the lithostratigraphic nomenclature of the St. Joe is not recognized. Instead, the equivalent interval is divided into the Bachelor, Compton, Northview, and Pierson Formations (Thompson 1986). To avoid this “state-line fault, these are recognized as members of the St. Joe Formation in Arkansas. The succeeding Boone Formation in Arkansas is separated informally into lower and upper divisions informally based on different types of chert development (Manger and Shelby 2000) (Fig. 2). However, like the St. Joe Formation, the Boone Formation is not recognized in Missouri, where the interval is divided into the Reed Springs, Elsey, and Burlington-Keokuk Formations (in ascending order) (Thompson 1986). The lower Boone is comprised of calcisiltites interbedded with dark, nodular penecontemporraneous chert. This chert represents the reprecipitation of silica derived from volcanic ash falling through the water column and accumulating below the sediment water interface before the carbonate sediment of the lower Boone was completely lithified. Alternatively, the upper Boone consists of crinoidal grainstones and packstones interbedded with white, to light gray, later diagenetic chert. The silica of the diagenetic chert was sourced from the same volcanic ash as the penecontemporaneous chert, but it is a groundwater replacement along the carbonate bedding planes (see Cains et al., this volume for further discussion of chert). The Short Creek Oolite, the only formally recognized member of the Boone, occurs in the upper part of the interval, but is only sporadically developed (McFarland 2004). This member was transported as down-ramp slurries during the upper Boone regression. The Boone Formation is separated by a type 1 sequence unconformity from succeeding strata of Moorefield or younger strata.

Sequence History

There are five different orders of eustatic cyclicity that produced the Lower Mississippian carbonate succession in the southern Ozarks. The first-order cycle named Kaskaskia (Sloss 1963) is bounded by type 1 sequence unconformities. It begins in the Lower Devonian and extends to the Mississippian-Pennsylvanian boundary. Its MFI occurred during the Lower Osagean. Two second-order cycles are present within the Devonian and Lower Mississippian portion of the first order sequence: Kaskaskia I and Kaskaskia II (Sloss 1982). Kaskaskia I begins at the base of the Devonian and extends to the type 1 sequence unconformity separating the Upper Devonian from the Lower Mississippian. The succeeding Kaskaskia II extends from the Lower Mississippian to the Mississippian-Pennsylvanian boundary, with its maximum flooding interval at the same point in the Lower Osagean as the first-order cycle. Superimposed on the Kaskaskia II cycle are two third-order cycles and 13 fourth-order cycles. The third and fourth order maximum flooding intervals occurred in the Lower Osagean. The first, third-order eustatic cycle of the Kaskaskia II cycle spanned the Kinderhookian – Osagean boundary in the upper St. Joe Limestone (Northview-Pierson contact), Lower Mississippian, which represents the TST (Manger and Shelby 2000). However, it is worth noting that during this transgression, there was a slight drop in sea level, most likely as a fourth-order cycle, allowing a terrigenous clastic influx, resulting in siltstone deposition of the Northview Member. Following this slight regression, transgression resumed, reaching the MFI in the lower Boone Formation (Fig. 4). The lower Boone MFI is coeval with those of the first-order Kaskaskia and the second-order Kaskaskia II cycles. The succeeding HST and RST sequences are represented by the upper Boone (Fig. 5), which becomes grain-dominated up-section as the regressive sequence brought deposition into effective wave base.

Conclusions

The Lower Mississippian (Kinderhookian-Osagean) of the southern Ozarks represents a single, third-order, transgressive-regressive eustatic cycle that is bounded unconformably by type 1 sequence boundaries. The St. Joe Formation (Kinderhookian-Osagean) represents the transgressive sequence and is composed of crinoidal packstones and carbonate muds.

The lower Boone Formation (Early Osagean) represents the maximum flooding interval and is composed of calcisiltites with dark, nodular penecontemporaneous chert, while the upper Boone Formation (Late Osagean) represents the highstand/regressive sequence and is composed of crinoidal packstones and grainstones with white to light gray, later diagenetic chert. Both the St. Joe and Boone Formations are separated unconformably from older and younger strata at their base and top, respectively.

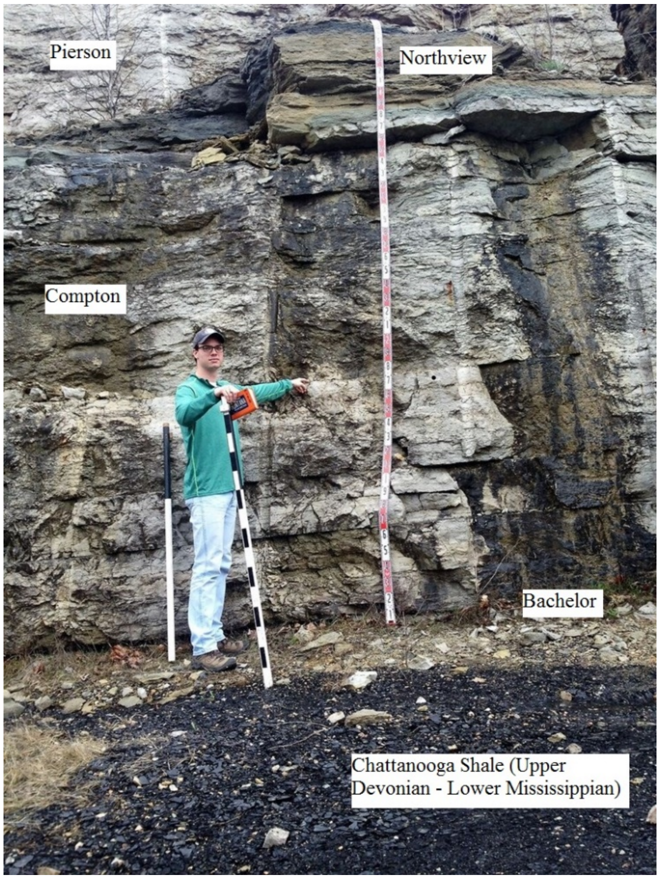

Fig. 3. Outcrop of St. Joe Formation (TST) exposing each member, I-49 road-cut near Jane, Missouri.

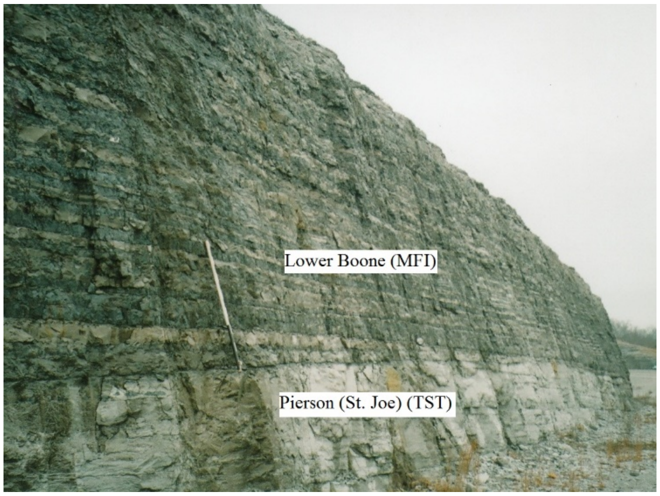

Fig. 4. Outcrop exposing the TST and MFI contact at the St. Joe-Boone boundary, I-49 road-cut near Pineville, Missouri.

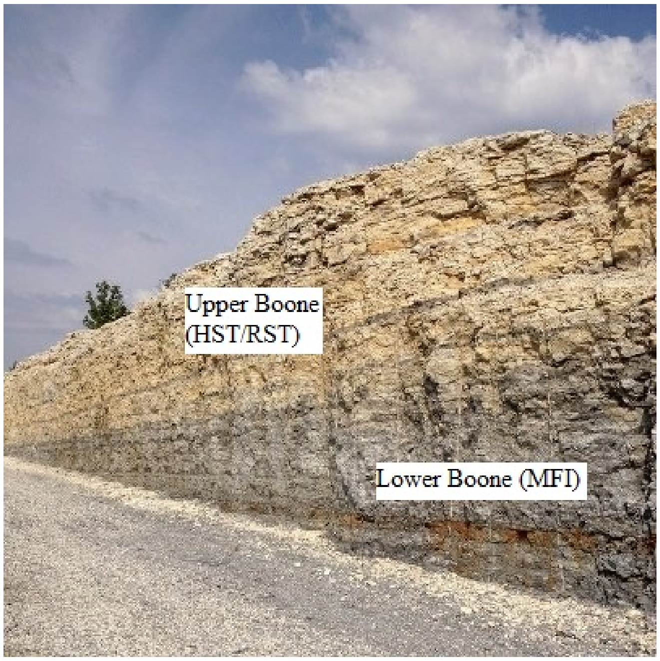

Fig. 5. Outcrop exposing the contact between the MFI and the HST/RST in the Boone Formation, I-49 road-cut near Pineville, Missouri.

Acknowledgements

Thanks to my co-workers in the Lower Mississippian Research Group in the Department of Geosciences – Julie Cains, Forrest McFarlin, John Philbrick, and advisor Dr. Walter Manger - for their help and support in seeing this paper to completion. The Department of Geosciences, University of Arkansas, defrayed page charges for this paper.

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Population Sampling of Chelonians in an Urban Lake in Jonesboro, Craighead County, Arkansas

J.D. Konvalina*, C.S. Thigpen, and S.E. Trauth

Department of Biological Sciences; Arkansas State University; P.O. Box 599, State University, AR 72467

*Correspondence: john.konvalin@smail.astate.edu

Running Title: Population Survey of Turtles

Abstract

We conducted a mark-recapture survey for aquatic turtles in Craighead Forest Lake in Jonesboro (Craighead County, Arkansas). From July 2, 2015 to October 14, 2015, we set six hoop nets, baited with fish parts, at specific shoreline locations around the lake. Traps were set twice a week and checked 12 hours after they were set. Carapace length, carapace width, plastron length, and plastron width were measured for each individual. Each turtle was identified to species and its sex was recorded. We also placed a notch in one or more of its marginal scutes to aid in future identification. Finally, a photo was taken of each individual's carapace and plastron. A total of six species were captured with Red-eared Sliders (*Trachemys scripta elegans*) being the most common. A single female Razor-backed Musk Turtle (*Sternotherus carinatus*) was found, which represented a new county record and the first documentation for this species above the 35°N parallel in Arkansas. The only recaptures were Red-eared Sliders. Using the Schnabel Index, we estimated there to be 171 Red-eared Sliders in Craighead Forest Lake. Our findings indicate a diverse chelonian community with a thriving Red-eared Slider population. Future studies should continue to examine the effect of urbanization on turtle population demographics.

Introduction

Urban sprawl has reduced the amount of available natural habitat for many animals (McKinney 2002). However, less natural habitat does not always directly correlate with population decline. A study in Australia, for example, found that the annual survival rate for freshwater turtles is not significantly different between suburbs and nature reserves (Rees et al., 2009). Likewise, adult survivorship was high (>84%) for two species of freshwater turtles in an urban Virginia lake (Mitchell 1988). For comparison, western chicken turtles (*Deirochelys reticularia miaria*) exhibited a 70% survival rate in an 11.4-ha floodplain wetland in central Arkansas, a rate considered low for chelonians (Dinkelacker and Hilzinger 2014). Another urban lake in Indiana contained six species of turtles with the Red-eared Slider (*Trachemys scripta elegans*) being the most abundant (Conner et al. 2005). Urban streams also support large populations of turtles and provide natural refugia from an ever-increasing wave of urbanization (Spinks et al. 2003, Plummer and Mills 2015).

This study investigated the chelonian composition of an urban lake in Jonesboro, Craighead County, Arkansas. A previous study surveyed the surrounding ditches in Jonesboro and found six turtle species with a composite Simpson's Index of Diversity value of 0.26 (Simpson 1949, Elston et al. 2016).

Materials and Methods

This study occurred at Craighead Forest Lake (24.3 hectares; 35.77894°N, 90.70923°W; WGS 84) in Jonesboro (pop. 71,551; 2010 Census) Craighead Country, Arkansas. This public lake was initially constructed by the Young Men's Civic Club in 1937 and is owned by the city. It is regularly stocked with fish by the Arkansas Game and Fish Commission and is located within Craighead Forest Park. Picnic tables, a campground, and playgrounds surround the lake, but there is a 365 m forest buffer between the lake and nearest city road.

To survey for chelonians three-ring hoop nets, 1.07 m in diameter, were baited with fish parts and placed in inlets scattered around the lake (Fig. 1). Six traps were set 19 times between 2 Jul 2015 and 14 Oct 2015 for a total of 114 trap nights. Traps were checked around 12 hours after they were set. Turtles were removed from the traps and the following measurements were recorded (in mm) using plastic calipers and a tape measure: straight carapace length, carapace width, plastron length, and plastron width. Sex of the individual was also recorded. Then, a triangular file was used to put notches in the marginal scutes of the turtle following the marking system of Cagle (1939). Finally, a photo was taken of each individual's carapace and plastron as a secondary method of identification.

Catch per unit effort (CPUE) was calculated for each species and all turtles as a whole (Gulland 1964). CPUE is calculated as the number of turtles divided by the number of trap nights for each species and then for all turtles as a whole. A Simpson's Index of Diversity (Simpson 1949) was calculated for the entire lake. Diverse communities are characterized as having a large number of species present along with an even distribution of the number of individuals per species. Finally, a Schnabel Index following Tanner (1978) was used to estimate the population size of species with recaptures.

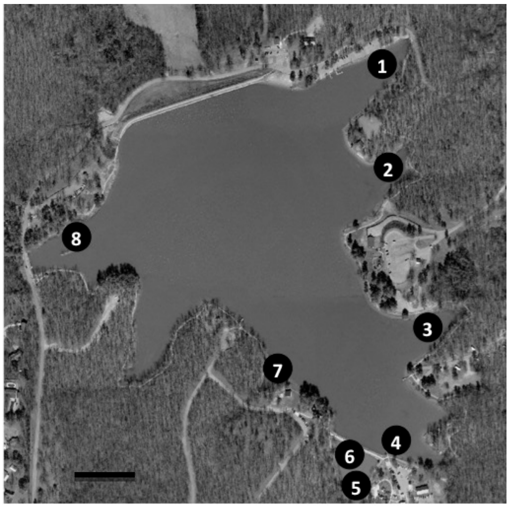

Figure 1. Map of Craighead Forest Lake with trap sites numbered. Bar = 100 m.

Results

A total of six species were captured: Spiny Softshell (*Apalone spinifera*), Snapping Turtle (*Chelydra serpentina*), River Cooter (*Pseudemys concinna*), Razor-backed Musk Turtle (*Sternotherus carinatus*), Eastern Musk Turtle (*Sternotherus odoratus*), and Red-eared Slider (*T. s. elegans*; Fig. 2). The most abundant species was *T. s. elegans* with a CPUE of nearly 0.5 (Table 1).

Species captured differed among months (Fig. 3). Likewise, species captures were not distributed evenly among trap sites (Fig. 4). A single female *S. carinatus* was sampled and represented a new county record (Arkansas State University Museum of Zoology 33368) and the first published record for this species above the 35°N parallel in Arkansas (Trauth et al., 2004).

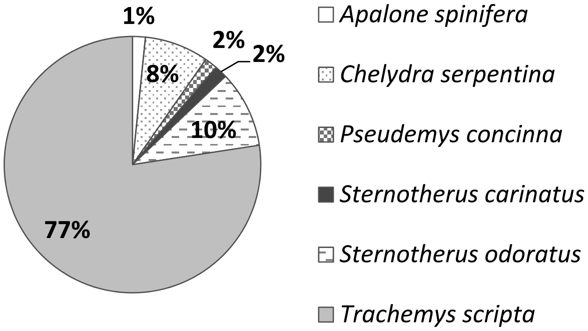

Figure 2. Overall capture percentages for each turtle species.

Table 1. Catch per unit effort (CPUE) for each turtle species.

All Turtle Species	0.54
Apalone spinifera	0.01
Chelydra serpentina	0.04
Pseudemys concinna	0.01
Sternotherus carinatus	0.01
Sternotherus odoratus	0.05
Trachemys scripta elegans	0.42

The Simpson's Index of Diversity was 0.39. The only recaptures were of *T. s. elegans*. Using the Schnabel Index, the *T. s. elegans* population was estimated to be 171 individuals. Movement between trap sites was not very extensive as the only major movement recorded was between sites 1 and 2. All other movements were between sites 5 and 6 or at the same site. Finally, *T. s. elegans* had a sex ratio that heavily favored females (0.64:1).

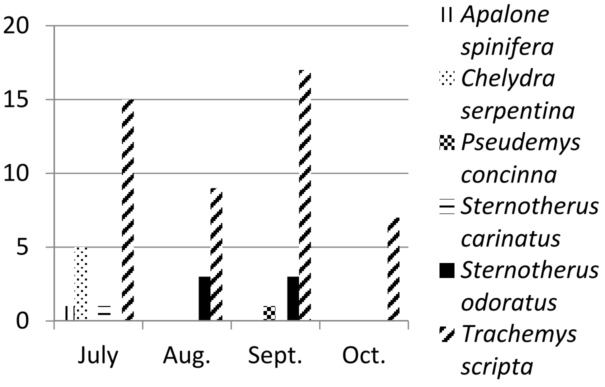

Figure 3. Frequency of each turtle species per month.

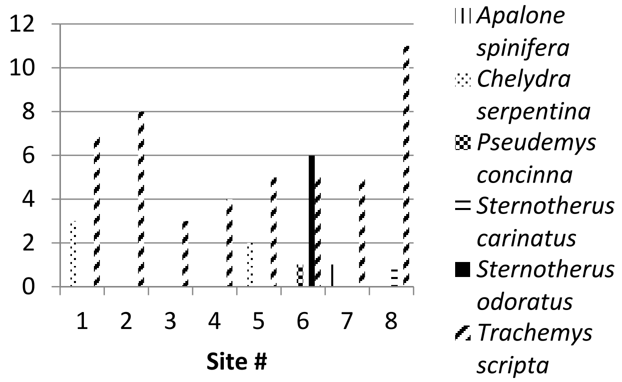

Figure 4. Frequency of each turtle species per trap site.

Discussion

Trachemys s. elegans was the most abundant species found in Craighead Forest Lake. This generalist is widespread throughout Arkansas and the entire southeastern United States and has been found in densities of up to 88 turtles per ha (Trauth et al. 2004). Similar percentages of *T. s. elegans* have been found in population surveys in both Indiana (Conner et al. 2005) and ditches around Jonesboro (Elston et al. 2016).

Many *P. concinna* were observed, but very few were captured, a fact corroborated by other studies (Trauth and Siegel 2016, Elston et al. 2016). Interestingly, the Simpson's Index of Diversity was slightly greater for Craighead Forest Lake than the surrounding ditches (0.39 vs. 0.26); yet, total abundance in both sites was dominated by *T. s. elegans* (77% and 85%, respectively; Elston et al., 2016). The increased diversity in Craighead Forest Lake was likely due to its larger surface area and variability in water depth compared to the ditches.

Only one *A. spinifera* was captured; however, there could be more individuals in Craighead Forest Lake than indicated by this sampling. While Plummer and Mills (2008) found large numbers of *A. spinifera* in an urban stream before and after channelization, other studies have reported very low numbers for this species. Only 8 turtles (2.8%) of 283 captured were *A. spinifera* in an Indiana lake (Smith et al. 2006), whereas in a 296-km section of the Missouri River a paltry 11 (0.4%) of 2,201 turtles sampled w *A. spinifera* (Bodie et al. 2000). Finally, this species made up only 12.9% (14 individuals) of all turtle captures in an Illinois pond (Dreslik et al. 2005).

No map turtles were found; however, there are multiple records for Mississippi Map Turtles (*Graptemys pseudogeographica kohnii*) and one record for Ouachita Map Turtles (*Graptemys ouachitensis ouachitensis*) in Craighead County (Trauth et al. 2004; Elston et al. 2016). These records were from drainage ditches and the St. Francis River, none of which connects with Craighead Forest Lake.

The lone *S. carinatus* sampled presents a puzzling challenge. All other published records are below the 35°N parallel. Humans could have transplanted the individual, perhaps as an unwanted pet; however, there are unpublished records for this species in adjacent Jackson and Lawrence counties and nearby Woodruff County, which suggests northeast Arkansas could house a viable population.

Sternotherus odoratus was found in Craighead Forest Lake and has previously been found in Craighead County; yet, they were not found in the surrounding ditches (Elston et al. 2016). The lack of ditch captures may be due to trap shyness, as Eastern Musk Turtles prefer still water such as those found in ditches.

Chelydra serpentina commonly migrates over land and a single female can colonize a body of water because of their ability to retain viable sperm for several years (Trauth et al. 2004). This may be the case with Craighead Forest Lake as it has a sizeable *C. serpentina* population, yet is isolated from other bodies of water.

Overall, this study adds to the idea that chelonians can do very well in urban environments. Future studies should continue to contribute to our knowledge of the effect of urbanization on turtle population demographics.

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Impact of Climate Variations on Soybean Yield in Eastern Arkansas: 1960-2014

J.W. Magugu[1*], S. Feng[2], Q. Huang[2], and K. Luthra[3]

[1]*Department of Geosciences, University of Arkansas, 113 Ozark Hall, Fayetteville, Arkansas 72701*
[2]*Department of Geosciences, University of Arkansas, 113 Ozark Hall, Fayetteville, Arkansas 72701*
[2]*Department of Agricultural Economics & Agribusiness, 217 Agriculture Building University of Arkansas Fayetteville, AR 72701*
[3]*Department of Biological & Agricultural Engineering, 228 Engineering Hall, 1 University of Arkansas, Fayetteville, AR 72701*

*Correspondence: jwmagugu@uark.edu

Running Title: Impact of Climate Variations in Eastern Arkansas: 1960-2014

Abstract

Climate is the major factor affecting crop production; therefore, various agro-meteorological indicators have been frequently used to evaluate the impact of climate on crop production. In this study, we examined the temporal variations of agro-meteorological indicators (growing degree days, total precipitation, dry spells and drought indices) during 1960-2014 and their impact on soybean yields in East Arkansas. Results show an increasing trend in growing degree days (GDDs) and dry spells, though the total precipitation during the soybean growing season remained nearly unchanged during the study period. Generally, GDDs and dry spells show a strong correlation with yields. We also evaluated drought variability based on different drought indices, including the Palmer Drought Severity Index (PDSI), the Standardized Precipitation Index (SPI) and the Standardized Precipitation-Evapotranspiration Index (SPEI). The drought indices are all negatively correlated to soybean yields. Overall, the one month SPEI showed the strongest impact on yields. After regression analysis, Dry spells and Total precipitation were the only significant factors in the General Linear Model (GLM).

Key words: Climate change, Agro-indicators, Drought indices

Introduction

Urbanization, salinization, climate change and water scarcity all pose renewed challenges to agriculture (Fedoroff et al. 2010). Increases in crop yields are required to meet both domestic and commercial demands for food, but climate change and diminishing returns from technological advancements will limit potential success (Lobell and Asner 2003). Temperatures above 30°C tend to diminish yields of most crops because of the photosynthetic threshold temperature. These elevated temperatures accelerate crop reproductive development thereby reducing accumulation of carbohydrates, fats and proteins that are major components of grains and fruits (Fedoroff et al. 2010). In fact, studies project 17% decreases in both corn and soybean yields for each degree rise in growing season temperature in the South East United States (Lobell and Asner 2003).

There is a general trend of early onset of spring and increasing growing degree days in the United States (Feng and Hu 2004, Schwartz and Reiter 2000). Previous satellite and climatological studies agree that there are shifts in timing and length of the growing season (Tucker et al. 2001). Increasing growing season length provides opportunities for earlier planting, ensuring maturation and possibilities of multiple cropping. However, higher temperatures could speed development and reduce time to accumulate dry mater, which in turn could cause slight decreases in yields (A.C.I. 2004, Linderholm 2006, Stocker et al. 2013). Additionally, variation in crop yields is more influenced by regional weather and climate rather than large scale climate dynamics. Therefore, it is more important to develop agro-meteorological indicators at the regional level to study their relationship with individual crop yields (Mishra and Cherkauer 2010).

The long term average, frequency and extremes of several weather variables are the chief determinant of the general climate of a region (Patel et al. 2007). To evaluate the impact of climate on agriculture, multiple agro-meteorological indicators are used. Agro-meteorological indicators are constructed from climatic variables that have an impact on plant life. They are used to assess site suitability for crop growth, geographical limits of crop land use and to establish estimates of weather anomalies or trends (Confalonieri et al. 2010). The study of both temperature and precipitation based indicators has never been more critical because varying climate has and will continue to alter agricultural environment and affect crop productions (Feng and Hu 2004).

There is a consensus that climate change will alter the frequency, timing and intensity of extreme events such as drought (Greenough et al. 2001). In fact, climate model simulations indicate that the interiors of northern continents will become drier during summer over the next century (Wetherald and Manabe 2002). Socio-economic and environmental effects of droughts are costly due to their spatial and temporal extent (Wilhite 2000). Thus, increased severity and frequency of droughts is a major concern to many stakeholders, increasing the need to measure and study drought impacts on crop yields (Sheffield and Wood 2008, Wang 2005).

Drought is the least understood yet most complex of all natural hazards (Patel et al. 2007). Most elements of drought (onset, duration, intensity and end) are determined by moisture deficits (Kogan 1997, Vicente-Serrano et al. 2010). Due to dependence on water resources and soil moisture for crop growth, agriculture is often the first sector to be affected by onset of drought, making reductions in crop yields a good indicator for the impact of drought on agriculture (Kogan 1997, Narasimhan and Srinivasan 2005). The costliest droughts occur during the grain filling period of most crops. Corn and soybean, for example, are most severely affected when drought occurs during the grain filling period (Mishra and Cherkauer 2010). Nonetheless, lack of a universal drought monitoring framework makes it impossible to assess drought impacts across ecosystems and different countries' economies (Kogan 1997).

Monitoring, early warning and assessment of consequences of drought are the most common tools used in drought mitigation. Most countries' drought watch systems are based on analysis of weather anomalies or domestic indices, which are formulated by integrating temperature, rainfall and evapotranspiration (Kogan 1997, Patel et al. 2007). Drought indices must be associated with specific timescales to be useful for monitoring different types of drought (Patel et al. 2007, Vicente-Serrano et al. 2010). According to Vicente-Serrano et al (2009), PDSI was found to explain variability in production and activity of natural vegetation better than SPI. Patel et al (2007) also found that 3-month SPI could help assess in advance the decline in food and grain production caused by droughts in India (Gujarat State). In this paper, we considered three drought indices i.e. Palmer Drought Index (PDSI), Standardized Precipitation Index (SPI) and Standardized Precipitation and Evapotranspiration Index (SPEI).

Our study focuses on East Arkansas, where the majority of agricultural activity in the state occurs. Arkansas is a major agricultural producer and the largest producer of rice in the nation, with other major crops including soybean, corn, wheat and cotton (Nickerson et al. 2011). Arkansas's agriculture is heavily irrigated and is the fourth largest user of groundwater for irrigation in the nation (Holland 2007, Schaible and Aillery 2012). The climate of Arkansas is humid sub-tropical, with average temperatures of about 15.8˚C (Feng et al. 2014). The major rainy seasons in Arkansas occurs from March to May and then from October to December. Climate change may affect Arkansas' agriculture both directly through its effect on crop growth and indirectly through its effect on irrigation water supply. This study will explore the relationship between, Agro-meteorological indicators and crop yields in East Arkansas. We will also examine the performance of various indices to draw conclusions for policymakers and stakeholders.

Methods

Study Region

The study sites encompass 3 eight-digit hydrological unit code watersheds (L'anguille, Big, and the Lower White), within the farming region of the Arkansas Delta where the Mississippi alluvial aquifer is most depleted. The study area consists of 11 counties located in East Arkansas (Figure 1). It lies within latitudes 35.99 and 33.95 degrees North and longitudes 90.29 and 91.34 degrees West. The area is geographically homogenous: a predominantly flat alluvial plain in the Mississippi River Valley in Eastern Arkansas. This region is the most agriculturally productive region in Arkansas, producing rice, soybean, corn, wheat and cotton.

Data

The daily temperature (minimum, maximum and mean) and precipitation from the 11 counties in the study regions from 1960 to 2014 were obtained from National oceanic and Atmospheric administration (NOAA) (DeGaetano et al, 2015). Soybean was chosen for the study due to ease of non-irrigated soybean data availability. The LOESS regression method was used to remove trends in soybean crop yield arising from genetic and management improvements (Mishra and Cherkauer 2010).

Temperature Based Indicators

Growth events of crops such as flowering and maturity depend on the accumulation of specific quantities of heat or thermal time (Miller et al. 2001). Growing Degree Days (GDDs) is therefore a measure of heat accumulation necessary for maturity (Feng and Hu 2004, Hassan et al. 2007).

The calculation of thermal time (TT) in the unit of GDD is given by the following equation:-

$$TT = \sum_{Pb}^{Pe} \frac{(T_{max} + T_{min})}{2} - T_b$$

where T_{max} and T_{min} are the daily maximum and minimum surface air temperature; P_b and P_e are the beginning and ending dates of the growth season (Feng and Hu 2004). The base temperature (T_b) for growth was set as 10˚C for soybean (Feng and Hu 2004, Sarma et al. 2008). The threshold temperatures T_{min} and T_{max} was set as 10˚C and 30˚C respectively. The growing season (June, July, August, September & part of October/JJASO) for soybean was set between June 1st (P_b) and October 16th (P_e) from University of Arkansas Division of Agriculture Cooperative Extension Services (http://www.uaex.edu/).

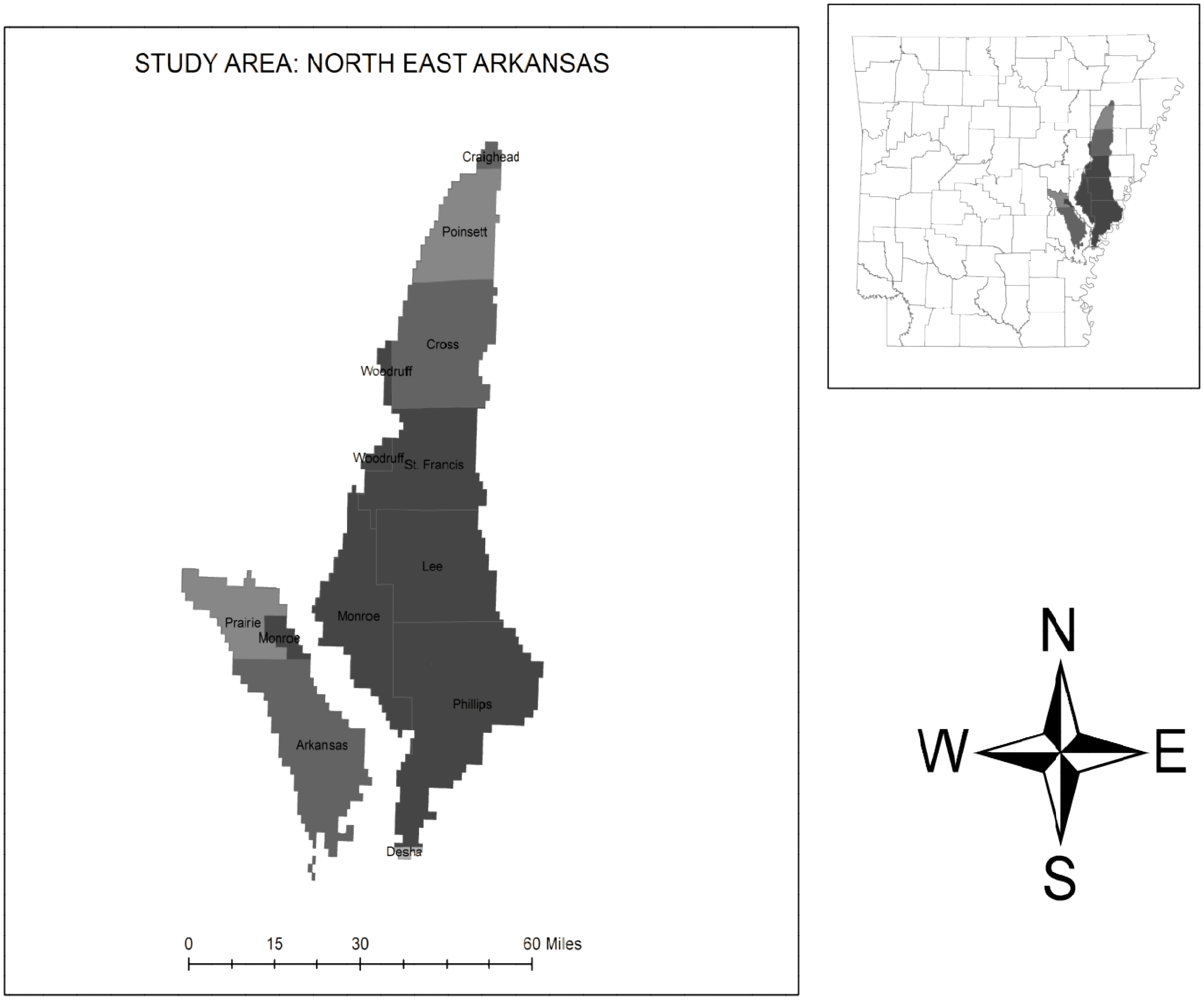


Figure 1. Study area in East Arkansas

Precipitation Indicators

Growing season total precipitation was calculated from daily precipitation data representing cumulative rainfall totals for the growing season (Kunkel et al. 1999). Dry spells during the growing season were defined as consecutive dry days without precipitation or when precipitation is below 1mm (Piani et al., 2010). Dryness and wetness are relative to historical average rather than absolute total of precipitation for given areas (Patel et al. 2007).

Drought indices

Different drought indices were used to evaluate the impact of the drought on crop yields (Heim Jr 2002). The three frequently used drought indices are the Palmer Drought Severity Index (Alley, 1984; Wells et al. 2004), the Standardized Precipitation Index (McKee et al. 1993, Patel et al. 2007) and the Standardized Precipitation-Evapotranspiration Index (Begueria et al. 2014).

The PDSI is the most common meteorological index used in USA. It is a standardized measure, ranging from -10(dry) to + 10(wet)(Dai et al. 2004). Since PDSI has a time span of 9 months or longer, it does not allow detection of droughts over different periods at multiple time scales and differentiation among different drought types (Hayes et al. 1999, Vicente-Serrano et al. 2010). For these reasons, PDSI responds slowly to drought and can retain values reflecting drought even after climatological recovery from drought has occurred (Hayes et al. 1999).

SPI is produced by standardizing the probability of observed precipitation for a given duration. Moreover, SPI is designed to detect drought over different periods at multiple time scales (1, 3 & 6 months) in this study. Positive values of SPI indicate greater mean precipitation while negative values indicate less than the mean precipitation (Patel et al. 2007). The main undoing of SPI is that it only uses precipitation in its formulation. Therefore, It does not consider other variables that can influence droughts like temperature, evapotranspiration, wind speed and soil water holding capacity (Vicente-Serrano et al. 2010).

On the other hand, SPEI (1, 3 & 6 months) is based on precipitation and potential evapotranspiration (PET). SPEI combines sensitivity of PDSI to changes in evaporation demand (caused by temperature variations and trends) with the simplicity of calculation and the multi-temporal nature of the SPI. Therefore, use of drought indices that include temperature data in the formulation is preferable. SPEI is particularly well suited for detecting, monitoring and exploring the consequences of global warming on drought conditions (Vicente-Serrano et al. 2010). Based on daily temperature and precipitation, the monthly mean temperature and monthly precipitation totals in individual counties were computed and then used to calculate the PDSI, SPI and SPEI for Soybean growing season in this study.

Data analysis

The response variable, soybean yield, and all the other predictor variables i.e. Growing Degree Days (GDDs), Dry spell and SPEI-1 were screened for possible outliers to confirm the normality of data distribution (Royston 1992). Correlation analysis was done to assess individual agro-climatic indicators performance against soybean yields for individual counties and the entire study area. Pearson Correlation analysis was also done for all three drought indices to establish their relationship with soybean yield during the growing season for each county and study area. Finally, Multiple Linear Regression (MLR) was used to fit General Linear Models (GLM) for individual counties and the study area using JMP Pro 12 (Preacher et al. 2006).

Results and Discussion

Agro-climatic indicators and yield anomalies

Soybean yields for the study area (Figure 2a) have increased steadily from the 1960s to 2014. These increases in yields have been attributed to scientific improvement through breeding and improved scientific management (Feng and Hu 2004, Mishra and Cherkauer 2010). Figure 2 shows agro-indicator anomalies for the study area. Results reveal that the soybean yields are negatively correlated to dry spells during the 1980s late 1990s and 2000s. GDDs were highly correlated with dry spells, with longer dry spells corresponding to longer GDDs (Figure 3). In addition, total precipitation was positively correlated with yields. Higher yields were observed when there was a considerable increase in total precipitation. Similar studies by Feng and Hu (2004) also revealed that dry and wet spells had the largest effect on dry-land corn yield in Nebraska.

The correlation between agro-indicators and soybean yields is shown in Table 1. Growing season GDDs and Dry spells are negatively correlated with yields while total precipitation and SPEI-1 are positively correlated. These results show that both precipitation and temperature indicators have significant effect on soybean yields. Accordingly, the

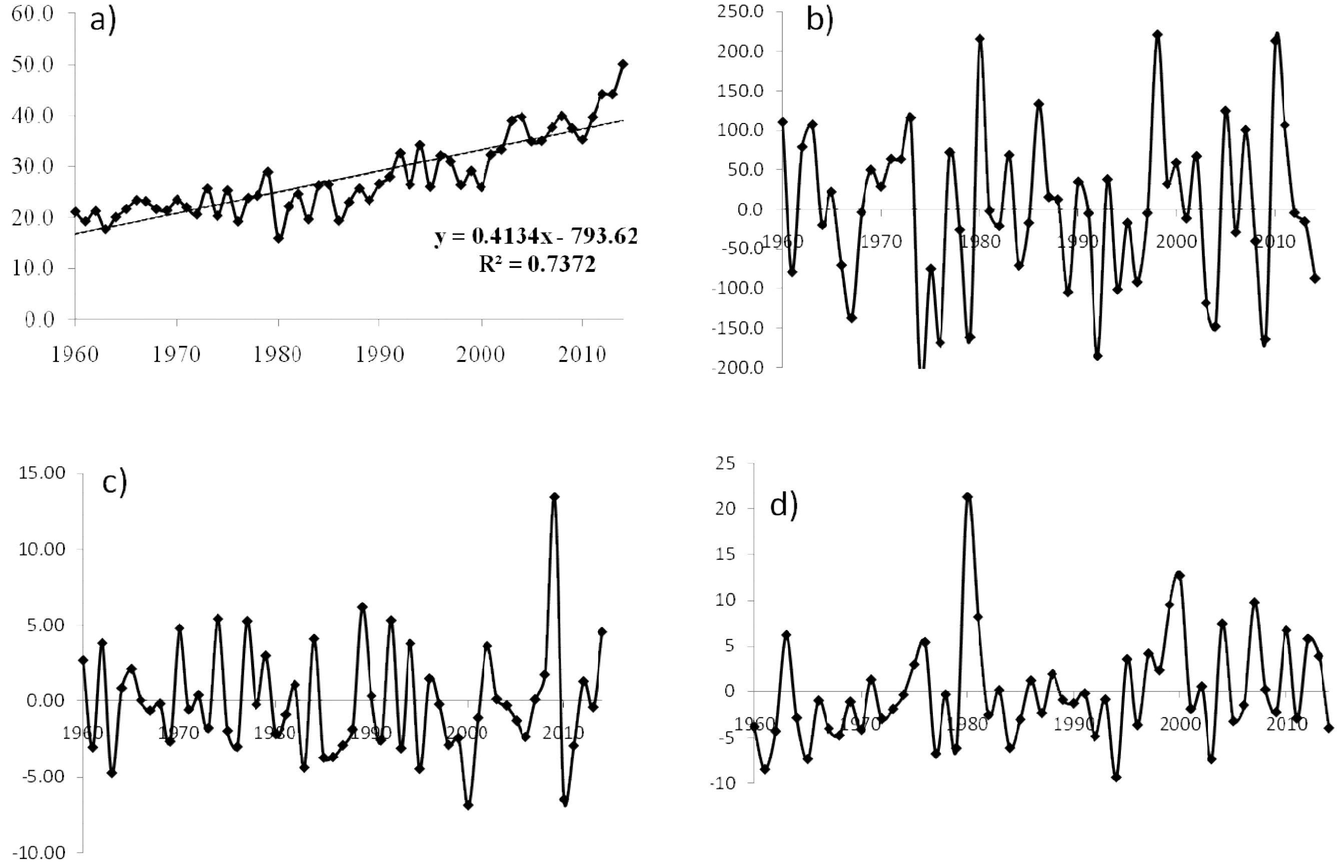


Figure 2: a) JJASO Soybean yields for study area (1960-2014), b) JJASO GDD anomalies (1960-2014), c) JJASO Total precipitation anomaly (1960-2014), and d) JJASO Dry spell anomalies (1960-2014) for East Arkansas.

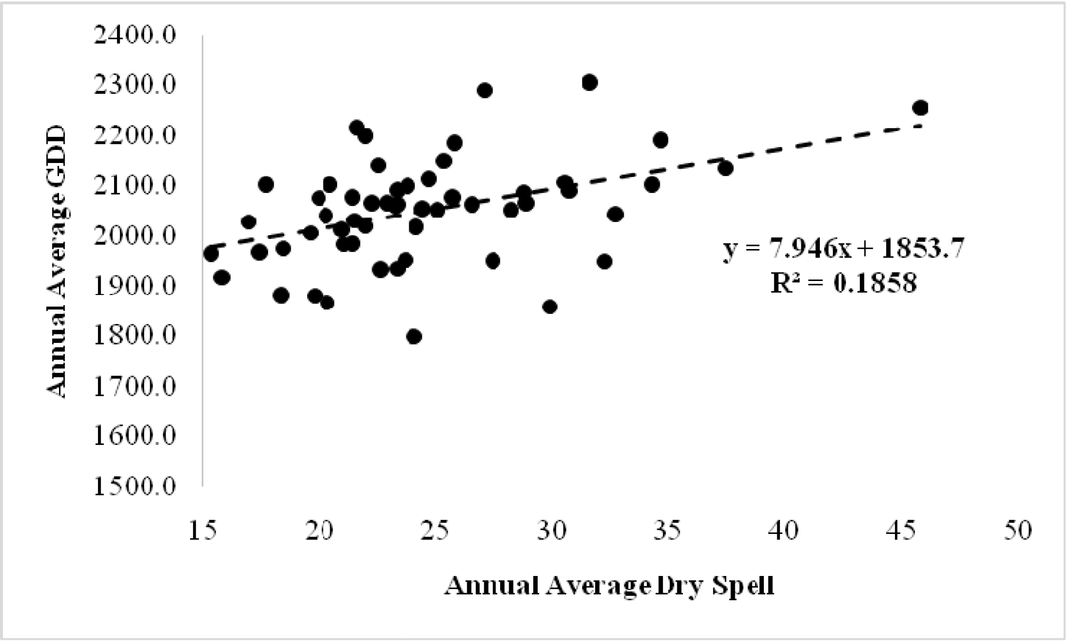


Figure 3: Correlation between GDD and Dry spell for the study area (1960-2014)

Table 1: Correlation between (JJASO) Agro-climatic indicators and Soybean yields (1960-2014)

County	GDD	Total precipi-tation	Dry spells	SPEI-1
Arkansas	**-0.197***	0.119	-0.044	**0.588*****
Craighead	-0.180	**0.328****	-0.033	**0.26****
Cross	-0.085	0.126	**-0.328*****	**0.201***
Desha	**-0.51*****	**0.210***	**-0.344*****	**0.412*****
Lee	**-0.211***	0.154	**-0.198***	**0.247***
Monroe	**-0.430*****	0.23	-0.075	**0.235***
Phillips	**-0.550*****	**0.314****	**-0.252***	**0.484*****
Poinsett	**-0.200***	**0.212***	**-0.283****	**0.313****
Prairie	-0.180	0.156	-0.188	**0.294****
St Francis	**-0.470*****	0.094	-0.086	0.121
Woodruff	-0.120	0.188	**-0.246****	**0.203***
Study area	**-0.311****	0.135	**-0.282****	**0.302****

*** indicates 99% confidence, ** indicates 95% Confidence and * indicates 90% confidence.

increase in dry spells resulting in accumulation of GDDs during the growing season is the factor most responsible for reduction in soybean yields in East Arkansas. Based on these results, it is very likely that global climate change will have great impact on agriculture through changes in precipitation and temperature.

Drought Indices and yield anomalies

Figure 4 shows PDSI and the 1-, 3- and 6- month SPEI and SPI for East Arkansas between 1960 and 2014. PDSI reveals major drought episodes in the 1960s, 1980s, mid- 1990s, and late 2005 and 2010. Although strongly correlated, SPEI and SPI also indicated drought during these time periods. These results reveal that, in circumstances where low variability of temperature occurs, both SPEI and SPI indices respond mainly to precipitation. These results are similar to those of Vicente-Serrano et al. (2010).

The JJASO drought indices were correlated with corresponding yield anomalies for each county (Table 2) of the soybean growing season for 1960-2014. The results showed significant positive correlation between these indices and de-trended Soybean anomalies for 8 of the 11 counties in the study area. Craighead county particularly had very high correlations (r >0.5) for all the three indices (PDSI, SPEI-1 and SPI-1). Differences in soybean planting dates during the crop growing season may explain the difference in correlations between the counties in the study area (Narasimhan and Srinivasan 2005). The results also reveal that drought indices may be a valuable instrument for forecasting soybean grain yield loss resulting from meteorological drought.

PDSI performed well in this study; it was positively correlated with seven instances of departures in soybean yields—six at the 99% confidence level and once at the 95% confidence level. SPEI-1, and was closely correlated to the yields for eight of the counties studied. Six of the counties were correlated at the 99% confidence level and while two were correlated at the 95% confidence level. SPEI-3 was also correlated with eight counties, but at lower confidence levels.

Table 2: Correlation between JJASO Drought indicators and de-trended Soybean yield anomaly (1960-2014)

County	PDSI	SPEI-1 month	SPEI-3 months	SPEI-6 Months	SPI-1 month	SPI-3 months	SPI-6 months
Arkansas	0.022	**0.232***	0.141	0.047	0.160	0.077	0.054
Craighead	**0.512*****	**0.501*****	**0.459*****	**0.368*****	**0.537*****	**0.468*****	**0.368*****
Cross	**0.531*****	**0.444*****	**0.371*****	**0.261****	**0.397*****	**0.338****	**0.237***
Desha	0.078	0.154	0.061	0.097	0.165	0.073	0.085
Lee	**0.332*****	**0.469*****	**0.505*****	**0.434*****	**0.410*****	**0.446*****	**0.395*****
Monroe	**0.320*****	**0.508*****	**0.426*****	**0.303****	**0.463*****	**0.402****	**0.278***
Phillips	0.071	**0.282****	**0.238***	0.141	**0.226***	0.176	0.081
Poinsett	**0.317****	**0.408*****	**0.345*****	**0.312****	**0.397*****	**0.311****	**0.270****
Prairie	**0.445*****	**0.433*****	**0.463*****	**0.326****	**0.392*****	**0.424****	**0.306****
St Francis	0.061	0.203	0.078	0.068	0.154	0.009	0.023
Woodruff	**0.267****	**0.282****	**0.238***	0.202	0.195	0.030	0.004
Study area	**0.367*****	**0.393*****	**0.345*****	**0.261****	**0.414*****	**0.334*****	**0.221***

***indicates 99% confidence, ** indicates 95% Confidence and * indicates 90% confidence

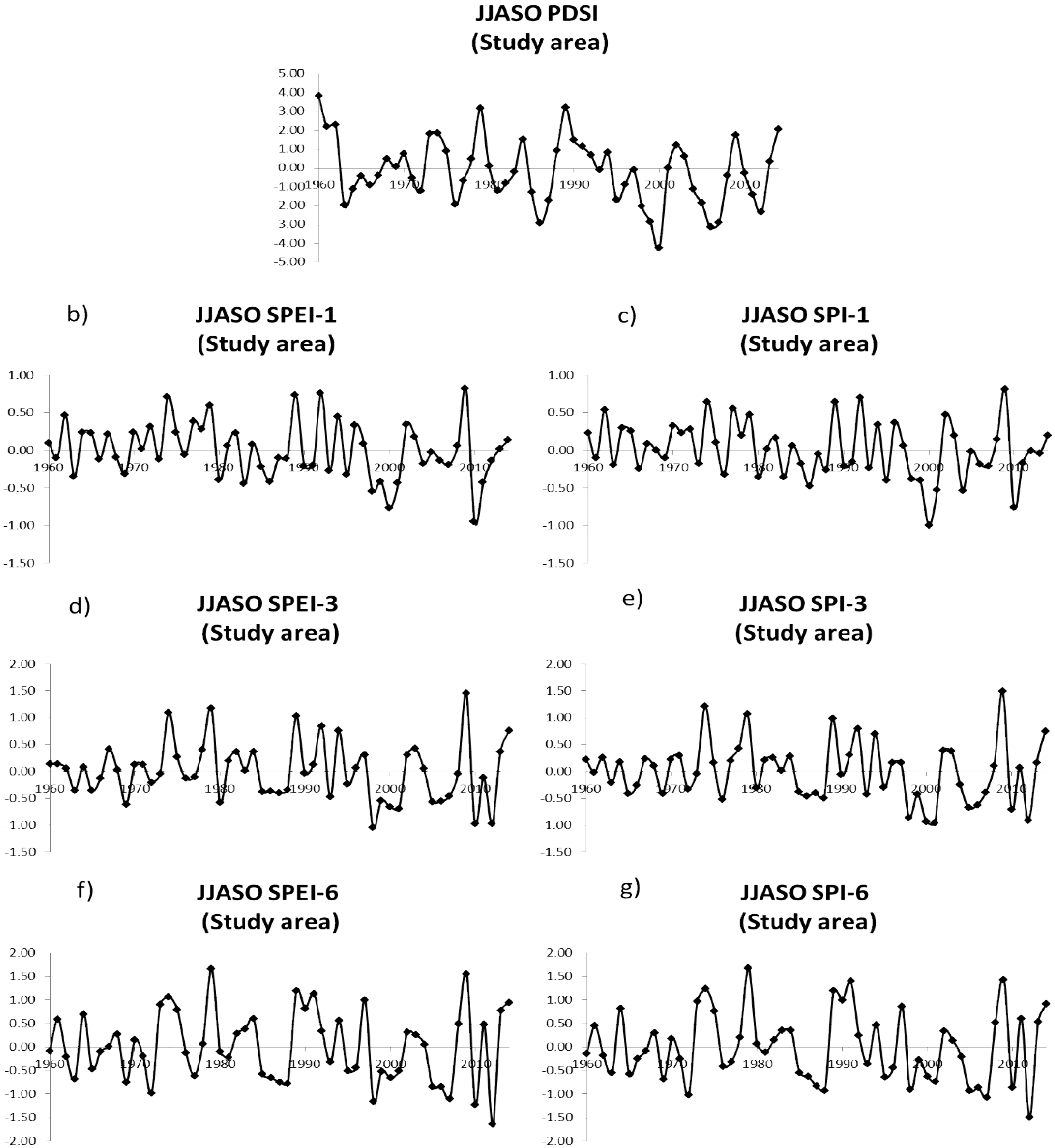


Figure 4: a) JJASO PDSI (1960-2014), b) JJASO SPEI-1month (1960-2014), c) JJASO SPI-1month (1960-2014), d) JJASO SPEI-3months (1960-2014), e) JJASO SPI-3 months (1960-2014), f) JJASO SPEI-6 months (1960-2014) and g) JJASO SPI-6 months (1960-2014).

Performance of the SPEI-6 was only significantly correlated to yields in 6 counties. These results reveal that SPEI based indices did better than PDSI save for SPEI-6. It is also important to note that the explanatory power of the SPEI diminishes as the time frame increases. For SPI, SPI-1 performed better with strong correlation in seven cases, six at the 99% confidence level. The explanatory power of the SPI indices also diminished as the time frame increased.In summary, SPEI indices outperformed PDSI and SPI. PDSI performed better than SPI, probably due to the inclusion of temperature in its computation. Short-term agricultural drought is best correlated to SPEI-1 and SPI-1. There are cases when drought indices do not exhibit meaningful correlation, as illustrated by their failure to indicate significant drought impact on yields in three of the 11 counties in the study area, where soybean was likely irrigated to mitigate drought impact. The absence of significant correlation for these counties may also result from low data quality of local weather stations.

Multiple Linear Regression

Multiple linear regression was performed with three agro-meteorological indicators (GDD, total precipitation and dry spell) to establish a GLM for each county and study area. Regression results for the counties and study area are shown in Table 3. Total precipitation and dry spell were the only factors explaining yield departures of soybean at 90% the confidence level in the final model for study area (Figure 5). The final model is shown below:-

$$Soybean\ Yield = b_0 - b_1 Dry\ Spell * + b_2 GDD - b_3 PRECIPITATION *$$

Where, b_0 is the intercept, b_1, b_2, and b_3 are the parameters of Dry spell, GDD, and Total precipitation respectively. Figure 5 shows that the total precipitation is significant at α = 0.056 and total precipitation significant at α = 0.027. The parameter estimates suggests, b_0 = 49.78, b_1 = -0.60, b_2 = 0.006 and b_3 = -0.125.

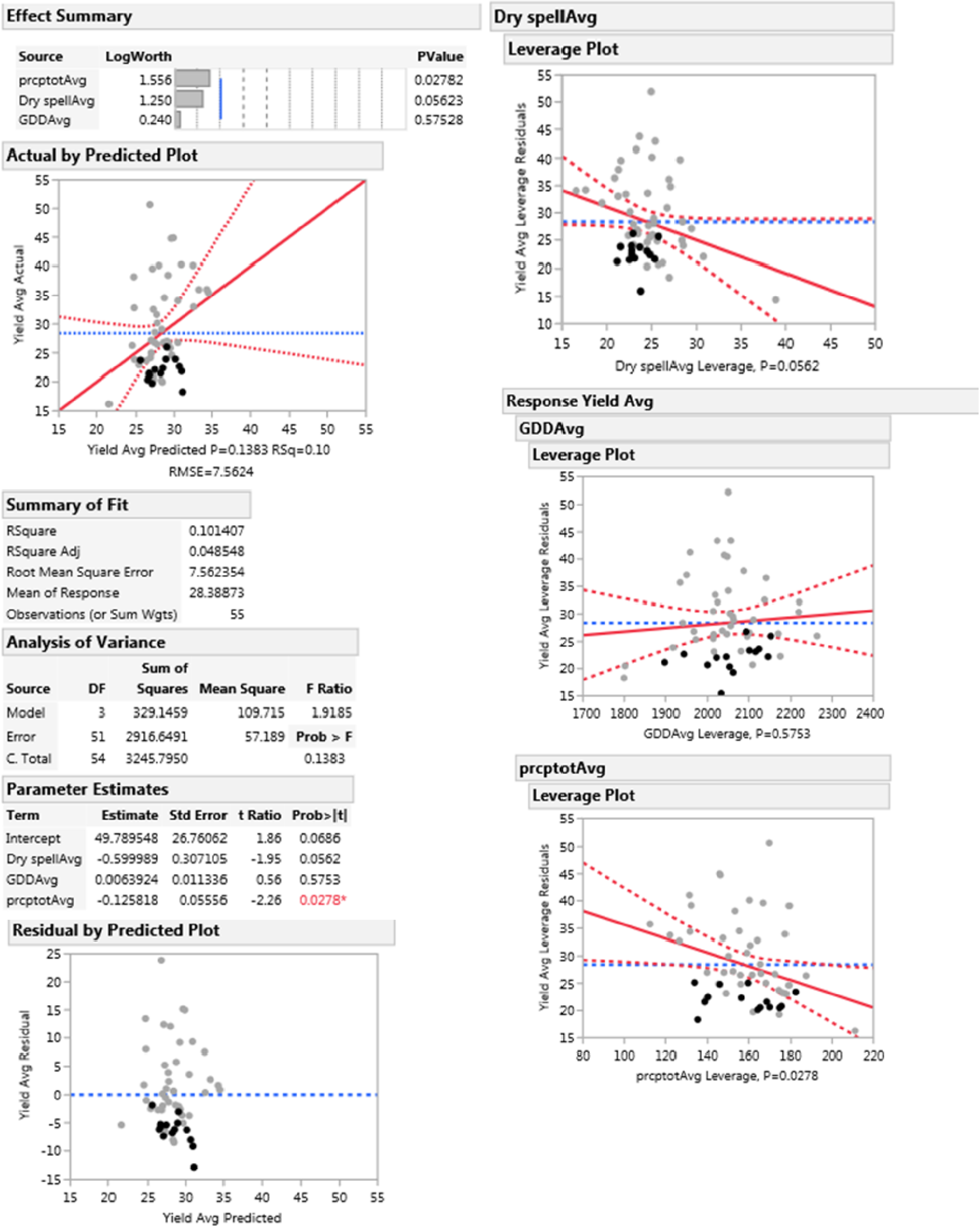
Conclusion

This study was carried out to explore the relationship between, Agro-meteorological indicators, drought indices and crop yields in East Arkansas. There was positive correlation between total precipitation and yields. Furthermore, GDDs and dry spells were negatively correlated with the yields. Dry spell and Total precipitation were the only factors explaining yield departures of soybean from the normal values in our multi-linear regression model developed for the study area. The increases in GDDS and dry spell during the crop growing season will serve to lower yields and increase the cost of doing agriculture in the study area. Coupled with global change, increased costs due to irrigation demands will hurt farmers by putting pressure on ground water.

Table 3: General Linear Models for individual counties and study area (JJASO)

County	Intercept	GDD	Total Precipitation	Dry Spell
Arkansas	-10	**0.02***	0.022	0.002
Craighead	47.62	-0.018	**0.11***	0.042
Cross	30	0.07	0.042	**0.28****
Desha	-44	**0.028*****	**0.07****	**0.21***
Lee	12.81	0.02	0.044	0.091
Monroe	-21.38	**0.076***	0.07	0.51
Phillips	-5.61	**0.04***	0.04	0.022
Poinsett	28.89	0.006	0.038	**0.207***
Prairie	30.69	0.008	**0.105****	0.044
St Francis	-18.51	**0.02***	0.07	0.018
Woodruff	19.22	0.002	0.06	**0.105***
Study area	49.78	0.006	**-0.125***	**-0.60***

***indicates 99% confidence, ** indicates 95% Confidence and * indicates 90% confidence



Effect Summary

Source	LogWorth	PValue
prcptotAvg	1.556	0.02782
Dry spellAvg	1.250	0.05623
GDDAvg	0.240	0.57528

Summary of Fit

RSquare	0.101407
RSquare Adj	0.048548
Root Mean Square Error	7.562354
Mean of Response	28.38873
Observations (or Sum Wgts)	55

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	3	329.1459	109.715	1.9185
Error	51	2916.6491	57.189	Prob > F
C. Total	54	3245.7950		0.1383

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	49.789548	26.76062	1.86	0.0686
Dry spellAvg	-0.599989	0.307105	-1.95	0.0562
GDDAvg	0.0063924	0.011336	0.56	0.5753
prcptotAvg	-0.125818	0.05556	-2.26	0.0278*

Figure 5: General Linear Model for soybean yields (1960-2014) for East Arkansas (JJASO)

While PDSI's efficacy was restricted to explanation of long-run drought impacts, it performed better than SPI indices. SPEI indices out performed both SPI and PDSI indices. SPEI and SPI indices, especially the one and three month indices, were closely correlated. PDSI was closely correlated to the SPEI-6 and SPI-6 indices. Importantly, short-term agricultural drought is best explained by SPEI-1 and SPI-1.

In cases where temperature trends are not apparent (relatively uniform), there was little difference in values obtained by precipitation indices like SPI or those formulated by potential evapotranspiration like SPEI. It is fair to conclude that in similar cases, precipitation data could be used to compute agricultural drought. SPI and SPEI-6 were strongly correlated to PDSI suggesting that precipitation was the most dominant factor in long term drought conditions. Due to negative effects of drought on agriculture and environment, agro meteorological indicators will play a critical role in long term studies for policy makers.

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The Ticks (Arachnida: Acari: Ixodida) of Arkansas

C.T. McAllister[1*], L.A. Durden[2], and H.W. Robison[3]

[1]*Science and Mathematics Division, Eastern Oklahoma State College, Idabel, OK 74745*
[2]*Department of Biology, Georgia Southern University, Statesboro, GA 30458*
[3]*Department of Biology, Southern Arkansas University, Magnolia, AR 71754-9354*

*Correspondence: cmcallister@se.edu

Running Title: Ticks of Arkansas

Abstract

Although ticks are a nuisance to humans and other animals, they are an important part of the biota of North America. In addition, they are vectors of many tick-borne disease agents that can negatively affect higher vertebrates. In Arkansas, there have been no recent comprehensive summaries of the ticks (Acari: Ixodida) in the last 40+ yrs. Here, we provide a summary of the ticks of the state and note the disease agents they can transmit.

Introduction

Ticks are ectoparasites that feed on the blood of various vertebrates, mainly birds and mammals, but some species parasitize amphibians and reptiles. They also serve as vectors of several tick-borne disease agents that affect humans and other vertebrates. The importance of ticks as vectors of pathogens in Arkansas has been highlighted previously (Anonymous 1995). In 2010, Arkansas ranked first among U.S. states for reported cases of tularemia (caused by *Francisella tularensis*), fourth for Rocky Mountain spotted fever (RMSF) (caused by *Rickettsia rickettsii*), and tenth in reported cases of Human Monocytic Ehrlichiosis (HME) (caused by *Ehrlichia chaffeensis*) (CDC 2010). Kardatke et al. (1992) documented a cluster of zoonotic pathogens [Spotted Fever Group Rickettsiae (SFGR), ehrlichiae and *Borrelia burgdorferi*] detected in ticks at Fort Chaffee, Arkansas. However, Trout-Fryxell et al. (2015) molecularly detected SFGR in 5 species of ticks from Arkansas and identified *Rickettsia montanensis* and *candidatus* Rickettsia amblyommii but not *R. rickettsia*, suggesting that some Arkansas cases diagnosed as RMSF may actually represent infections with other rickettsial agents. Tick paralysis can be caused by the release of certain salivary components by attached ticks (usually females) of some Arkansas ticks, especially *Dermacentor variabilis* but also (rarely) by *Otobius megnini, Amblyomma americanum, Amblyomma maculatum, Dermacentor albipictus, Ixodes scapularis* and *Rhipicephalus sanguineus* (Strickland et al. 1976, Durden and Mans 2016). Despite the medical and veterinary importance of ticks in Arkansas, some species may play an important biological role by promoting genetic diversity in host populations, regulating host population densities (either directly or indirectly by transmitting pathogens) and preventing overgrazing of plant resources (Durden and Keirans 1996a).

In Arkansas, Lancaster (1957a) was the first to produce a monograph on the ticks of the state. Later, Tugwell and Lancaster (1962, 1963) documented the hosts and seasonality of ticks in northwestern Arkansas. Lancaster (1973) provided detailed information of the ticks of Arkansas which included 18 species occurring in the state. Later, Ellis (1975) provided a synopsis of common Arkansas ticks and Lancaster (1979) provided a checklist of Arkansas ticks. Trout and Steelman (2010) surveyed 5 species of ticks parasitizing canines and/or deer in Arkansas (*A. americanum, A. maculatum, D. variabilis, I. scapularis* and *R. sanguineus*) and documented their seasonalities and distributions in the state. McAllister et al. (2013) reported on some ticks from sciurid rodents of the state, and Tumlison et al. (2015) provided records of ticks from several rodents. However, for more than 40 yrs (Lancaster 1973), there have been no attempt to provide a comprehensive list of Arkansas ticks.

The purpose of this report is three-fold: (1) update the ticks that currently occur in Arkansas including records of ticks accessioned into the United States National Tick Collection (USNTC) which is on long term enhancement loan to Georgia Southern University (GSU), (2) provide the most recent taxonomy on these ticks, and (3) note the species of ticks that are vectors for disease agents. Lancaster (1973) provided excellent diagnostic line drawings and illustrations for the 18 species of ticks he recorded from Arkansas. Diagnostic illustrations for an additional species (*Ixodes woodi*) we record here from the state can be found in Keirans and Clifford (1978) and Durden and Keirans (1996).

Methods

We conducted an exhaustive search of the scientific literature for information on Arkansas ticks. In addition, collection data on tick specimens deposited or recorded in the USNTC were examined. In the lists that follow, the following abbreviations are used:

A = Adult tick(s) (sexes were not determined for some older tick specimens deposited in the USNTC).
M = Male(s).
F = Female(s)
N = Nymph(s)
L = Larva(e)
*Collector (WJB = WJ Baerg SJC= SJ Carpenter; JLL=JL Lancaster; DAS = D.A. Saugey; FCW = FC Wonder)
RML (followed by a number) = accession number in the USNTC for the reported specimen(s).

All Arkansas tick specimens in the USNTC were examined; however, some older specimens had been returned to the submitters so the exact number of males, females or immatures in each collection could not always be determined. Common tick names listed follow the Common Names of Insects Database (Entomological Society of America 2016).

Results

We report a total of 3 argasid (soft tick) species and 16 ixodid (hard tick) species from 35 of 75 (47%) counties of Arkansas (Fig. 1). One of these, *I. woodi,* is reported from the state for the first time. Another species, *Rhipicephalus* (*Boophilus*) *annulatus,* has been extirpated from Arkansas, whereas an additional species, *Amblyomma maculatum* (Gulf Coast tick), has been expanding its range into this state. In addition to the species reported here, humans (or pets) returning to Arkansas from other parts of North America or the world could bring back attached non-native tick species.

Family Argasidae (soft ticks)

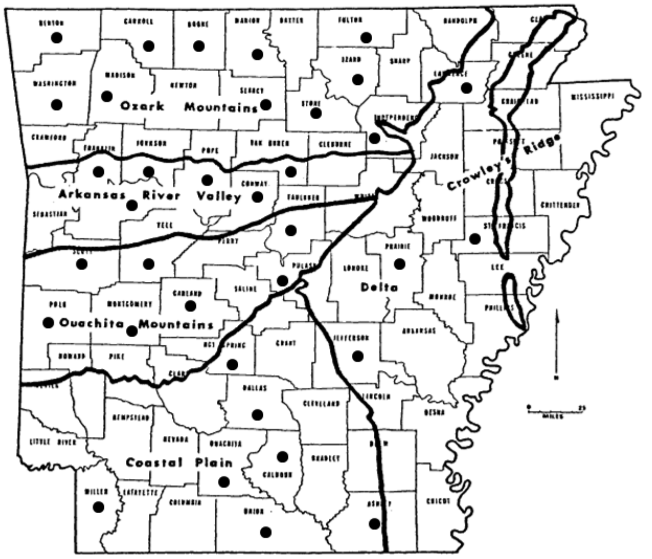

Figure 1. County outline map of Arkansas showing major physiographic regions with dots (●) in 35 counties having USNTC records of ticks; some counties have multiple records.

***Carios* (*Ornithodoros*) *kelleyi* (Dugés) – no common name.** A single specimen was reported by Lancaster (1973) in Stone County from a pigeon (more likely from a bat). Additional *O. kelleyi* were reported from cave-dwelling big brown bats, *Eptesicus fuscus*. This tick has been recorded from several species of bats across North America (Cooley and Kohls 1944a). *USNTC records* (Fig. 2): 1F, in building, Stone Co., Mountain View, 1952, JLL (RML 31120). 1M ex *Columbia livia,* Stone Co., Apr. 1954, JLL (RML 32974). 9L ex *E. fuscus,* Benton Co., War Eagle (bat cave), 3 Mar. 1962, JLL (RML 37888).

***Ornithodoros concancensis* Cooley and Kohls – no common name**. Lancaster (1973) reported this tick from a nest of an eastern phoebe (*Sayornis phoebe*) in Stone County (Fig. 2). However, it is typically an ectoparasite of bats and has also been collected from bat roosts (Cooley and Kohls 1944a).

***Otobius megnini* Dugés – ear tick.** Immature stages of this tick typically parasitize ungulates (but it can also feed on humans) and are often found in the internal ear canal where the spinose nymphal integument facilitates attachment. Adults do not feed. This tick is native to Mexico and the southwestern United States (Cooley and Kohls 1944a). However, livestock, especially cattle, moved from these regions can introduce *O. megnini* into new areas. This occurred in the early 1950s in Arkansas when herds of cattle were imported from Texas. Lancaster (1973) reported 3 established foci of this tick in Arkansas (Independence, Izard, and Yell counties) and reported other specimens from Franklin and Logan counties (Fig. 3). Lancaster

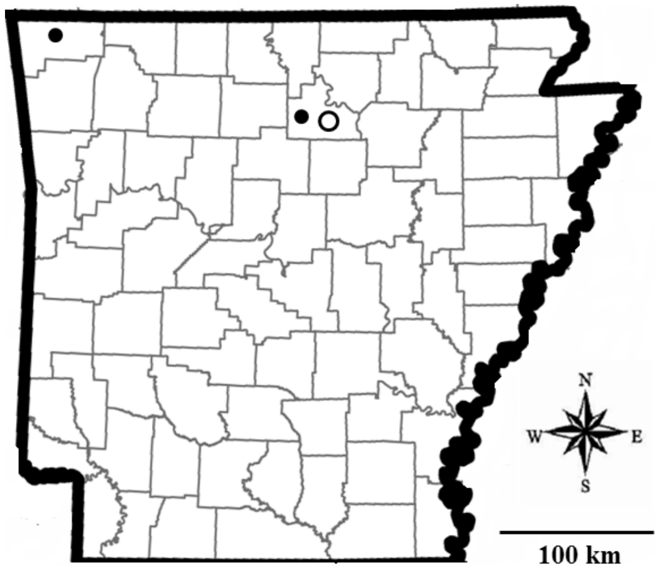

Figure 2. USNTC records of *Carios* (*Ornithodoros*) *kelleyi* (solid dots) and *Ornithodoros concancensis* (open dot) in AR.

(1984) advocated using acaricide-impregnated ear tags for controlling this tick on Arkansas livestock. There do not appear to be any currently established foci of this tick in Arkansas but humans visiting endemic areas or livestock being imported could be infested.

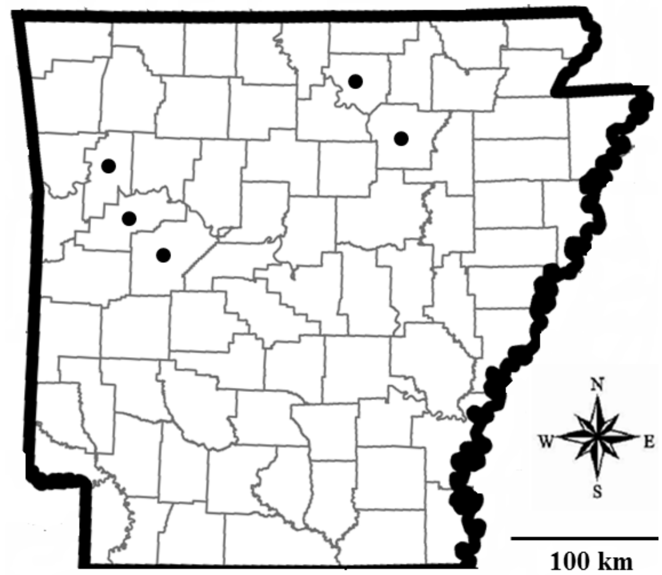

Figure 3. Records of *Otobius megnini* (solid dots) in AR.

Family Ixodidae (hard ticks)

***Amblyomma americanum* (Linnaeus) – Lone Star tick.** This is one of the most abundant tick species in the eastern United States (Cooley and Kohls 1944b). In Arkansas it almost certainly occurs in every county although USNTC voucher specimens are available for only 21 counties (Fig. 4). Adults parasitize a variety of medium to large-sized mammals, especially white-tailed deer (*Odocoileus virginianus*), whereas immatures feed on various birds and mammals (Cooley and Kohls 1944b, Richardson et al. 1994, Polechla was 1996). The host list for the Lone Star tick in Arkansas summarized by Lancaster (1973) and included several mammals as well as birds. Koch (1982) reported *A. americanum* to be the second most abundant tick parasitizing domestic dogs in northwestern Arkansas. Lancaster (1955, 1957a, b), Lancaster et al. (1982a, b) and Meyer et al. (1982) provided data on the biology, seasonality and control of *A. americanum* in Arkansas. Hair and Howell (1970) studied the biology and control of this tick in Ozark recreation areas. Trout et al. (2010a) provided data on the population genetics of *A. americanum* in Arkansas. Trout and Steelman (2010) documented a wide distribution for *A. americanum* in Arkansas with most specimens being collected from canines and deer from May through August.

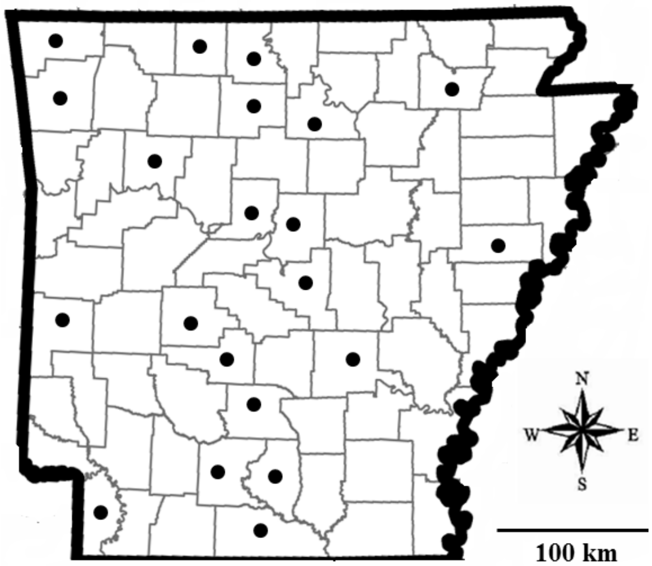

Figure 4. USNTC records of *Amblyomma americanum* (solid dots) in AR.

Washburn and Tuohy (1949) discussed the high prevalence of tularemia in humans and wildlife in Arkansas and Calhoun (1954) highlighted the role of *A. americanum* as a vector of *F. tularensis* in Arkansas. Eisen (2007) recommended additional investigations into tick-borne transmission of *F. tularensis* in Arkansas and Missouri. *Amblyomma americanum* is also a vector for several other agents, including those that cause HME, a form of granulocytic ehrlichiosis caused by *Ehrlichia ewingii*, Southern Tick Associated Rash Illness (STARI) (possible agent, *Borrelia lonestari*), American boutonneuse fever caused by *Rickettsia parkeri* and feline cytauxzoonosis caused by *Cytauxzoon felis* (Childs and Paddock 2003, Goddard 2003, Trout and Steelman 2010, Killmaster et al. 2015). Further, *A. americanum* has been implicated as a zoonotic vector of 2 recently documented human pathogens, Heartland virus in Missouri (Savage et al. 2013) and Bourbon virus in Kansas (Kosoy et al. 2015). Cross reactivity between salivary proteins from *A. americanum* and galactose-α-1,3-galactose ("alpha-gal") in consumed food can also lead to red meat allergies in humans (Commins et al. 2011). Although this tick has not historically been considered to be a vector of *R. rickettsii*, Breitschwerdt et al. (2011) documented transmission of this agent by *A. americanum* in North Carolina. Goddard and McHugh (1990) documented severe parasitism by *A. americanum* of military personnel at Little Rock Air Force Base during field training exercises. Schwartz et al. (1996) reported anti-tick salivary gland protein antibody seroconversion in military personnel exposed to *A. americanum* bites at Fort Chaffee. More recently, McAllister et al. (2013a) reported 5 and 24 nymphs of *A. americanum* on 2 eastern fox squirrels (*Sciurus niger*) from Marion County.

USNTC records: Ex *Canis familiaris* (104A) & *B. taurus* (134A, 1N), Boone Co., Harrison, 6–7 Jun. 1938, C.B. Philip & D. Conroy (RML 14191–14192, 14196). 1M, 1F ex *Equus caballus*, Boone Co., Harrison, C.B. Philip & D. Conroy, 6 Jun. 1938 (RML 14193). 12A ex *E. caballus* & *Bos taurus*, Boone Co., near Alpena, 6 Jun. 1938, C.B. Philip & D. Conroy (RML 14813). 1F ex *Homo sapiens*, Benton Co., Fayetteville, May 1938, H.H. Schwardt (RML 14816). 2M,2F, 1N ex *C. familiaris*, Boone Co., Lead Hill, 14 Mar. 1939, SJC (RML 15506). 16M, 12F ex *C. familiaris* & *B. taurus*, Dallas Co., Sparkman, 3 Apr. 1939, SJC (RML 15516–15517). 8F ex *B. taurus*, Calhoun Co., Locust Bayou, 4 Apr. 1939, SJC (RML 15520). 1F, 18N, 60L, host not stated, Boone Co., near Bergeman, 2 Aug. 1939, SJC (RML 16005). 4A, 12N ex *C. familiaris*, Boone Co., Harrison, 1 Aug. 1939, S.J. Carpenter (RML 16006). 14M, 75F ex *C. familiaris*, *E. caballus* & *B. taurus*, Marion Co., near Lead Hill, 5 Jul. 1939, SJC (RML 16653). 26M, 82F ex *C. familiaris*, Boone Co., Bergeman, 7 Jul. 1939, SJC (RML 16654). 18M, 42F ex *C. familiaris*, Boone Co., near Denver, 6 Jul. 1939, SJC (RML 16655–16656). 38N, 22L, host & date not stated, Garland Co., H. H. Little (RML 19047–19048). 1N, 5L ex *C. familiaris*, date not stated, Garland Co., H.H. Little (RML 19049). 2N ex *H. sapiens*, locality not stated, 3 Sept. 1941, W.J. Gertsch (RML 19586). 3N ex *H. sapiens*, Hot Springs, Garland Co., 20 Jun. 1943, WJB (RML 19690). 1M, host not stated, Washington Co., near Fayetteville, 20 Jun. 1943, WJB (RML 20274). 1F ex *H. sapiens*, Washington Co., near Fayetteville, 10 Jul. 1943, WJB (RML 20291). 1F, host not stated, Union Co., near Marysville, Jul. 1943, WJB (RML 20292). 2F, 1N, host not stated, Ouachita Co., near Camp Albert Pike, Jul. 1943, WJB (RML 20293). 1N ex *H. sapiens*, Lawrence Co., Blackrock, 7 Sept. 1942, C.R. Joyce (RML 22080). 2N ex *Sciurus niger*, Boone Co., 1 mi S. Valley Springs, 20 Apr. 1947, H.B. Hungerford (RML 23729). 23M ex *C. familiaris*, Boone Co., 1 mi S. Valley Springs, 18 Apr. 1947, H.B. Hungerford (RML 23743). 1M, 1F, host not stated, Benton Co., Rogers, Devil's Den, 6 Jun. 1946, M.W. Sanderson (RML 23755–23756). 233A ex *E. caballus*, *B. taurus* & drag cloths, Polk Co., 4 mi SW Mena, 3-4 July 1947, J. M. Brennan (RML 23884–23889) 12A, 10N ex *B. taurus*, *C. familiaris* & vegetation, Polk Co., 1 mi SW Hatfield, 6 Jul. 1947, J.M. Brennan (RML 23890–23892). 30A, 3N ex *C. familiaris*, Polk Co., 3.5 mi NW Hatfield, 7 Jul. 1947, J.M. Brennan (RML 23893). 25A, 50N, drag cloth, Polk Co., 3.5 mi NW Hatfield, 7 Jul. 1947, J.M. Brennan (RML 23894). ex *S. niger* (1N), *C. familiaris* (2A, 4N, ~40L), *Sylvilagus floridanus* ("several" L) & drag cloths (28A, ~250N), Polk Co., 5 mi NW Hatfield, 7–8 Jul. 1947 (RML 23896–23901). 51A ex *B. taurus*, Polk Co., 10 mi W. Mena, 11 Jul. 1947, J. M. Brennan (RML 23904). 2L ex *H. sapiens*, Washington Co., Fayetteville, 1945, WJB (RML 24021). 1M ex *Felis catus*, Washington Co., 29 Apr. 1950, WJB (RML 27777). 2M ex *Felis catus*, Benton Co., 6 May 1950, WJB (RML 27778). 3F, 2N ex *F. catus*, Searcy Co., 21 Mar. 1950, WJB (RML 27779). 1F ex *F. catus*, Faulkner Co., 21 Mar. 1950, WJB (RML 27780). 1N ex. *H. sapiens*, Hot Spring Co., 8 Apr. 1950, WJB (RML 27781). 1M, 2F ex *H. sapiens*, Conway Co., 14 Mar. 1950, WJB (RML 27782). 1N ex *H. sapiens*, Washington Co., 14 Mar. 1950, WJB (RML 27783). 11M, 3F, 1N ex *E. caballus*, Washington Co., May 1950, WJB (RML 27784–27785). 1F ex *E. caballus*, Miller Co., 9 Apr. 1950, WJB (RML 27786). 1M, 7F ex "rabbit," Washington Co., 5 May 1950, W.J. Baerg (RML 27788). 1N ex "rabbit," Searcy Co., 21 May 1950, WJB (RML 27789). Ex *Ovis aries* (2M, 3F), *B. taurus* (1N) and *C. familiaris* (1N), Washington Co., Apr. & May 1950, WJB (RML 27790, 27792–27793). 1N ex *C. familiaris*, Hot Spring Co., 8 Apr. 1950, WJB (RML

27795). 4N, ex *C. familiaris,* Pulaski Co., 11 May 1950, WJB (RML 27796). 2F ex *C. familiaris,* Ouachita Natl. Forest, 13 May 1950, WJB (RML 27797). 1F ex *C. familiaris,* Washington Co., 21 May 1950, WJB (RML 27799). 1F ex *C. familiaris,* St. Francis Co., 6 mi N. Forrest City, 1 Aug. 1951, E.L. Calhoun (RML 30760). 26 N, ex *S. floridanus,* Stone Co., Marcella, 24 Mar. 1948, F.C. Wonder (RML 31808). 2N, ex *N. floridana,* Stone Co., Marcella, 25 Mar. 1948, FCW (RML 31811). 1M, host not stated, Lawrence Co., Jul. 1922, B.C. Marshall (RML 31813). 10L ex *C. familiaris,* Jefferson Co., Pine Bluff, 26 Jul. 1940, J. D. Morton (RML 57348). 14 N ex *O. virginianus* Miller Co., Texarkana, 6 Aug. 1911, “G.N.W.” (RML 57735). 1M, 3F ex *H. sapiens,* “Pettigrew and Rich mountains,” Jun. 1910, A.H. Howell (RML 57748). 1M, host not stated, Dallas Co., 10 Jun. 1973, M. J. Rowland (RML 105740). 2M, 1F, 3N ex *Lontra canadensis,* localities and dates not stated, P.J. Polechla (RML 117912–117914). 1F, vegetation, Pulaski Co., Little Rock Air Force Base, 23 Jul. 1987, J. Goddard (RML 118550). 1M ex *H. sapiens,* Johnson Co., Ozark Natl. Forest, 5 Jun. 1990, W.T. Denny (RML 119978).

***Ambylomma maculatum* (Koch) – Gulf Coast tick.** Historically, this tick has not been common in Arkansas but its range has been expanding northwards from the Gulf Coast region in recent years (Teel et al. 2010, Paddock and Goddard 2015). It is now established in Arkansas (Trout and Steelman 2010, Trout et al. 2010b). Adults feed on a variety of large mammals such as deer and cattle whereas immatures feed on smaller mammals and on birds (Cooley and Kohls 1944b, Teel et al. 2010). Lancaster (1973) recorded *A. maculatum* from Ashley County on cattle and from Washington County via dragging techniques. Koch (1982) documented *A. maculatum* from domestic dogs in northwestern Arkansas. This tick is a vector for the causative agent of American boutonneuse fever, *R. parkeri* and its attachment can also cause a disfiguring condition called gotch ear in livestock animals that can lead to secondary bacterial infections (Teel et al. 2010, Paddock and Goddard 2015). Trout et al. (2010c) detected *R. parkeri* and *Candidatus* Rickettsia amblyommii in *A. maculatum* from Arkansas.

USNTC records (Fig. 5): 1M ex *C. familiaris,* Hot Spring Co., 4 mi E. Point Cedar, 26 Jul. 1950, C.E. Hopla (RML 27731). 1M ex *H. sapiens,* Pope Co., near Russellville, 22 Jul. 1993, C.D. Steelman (RML 121362).

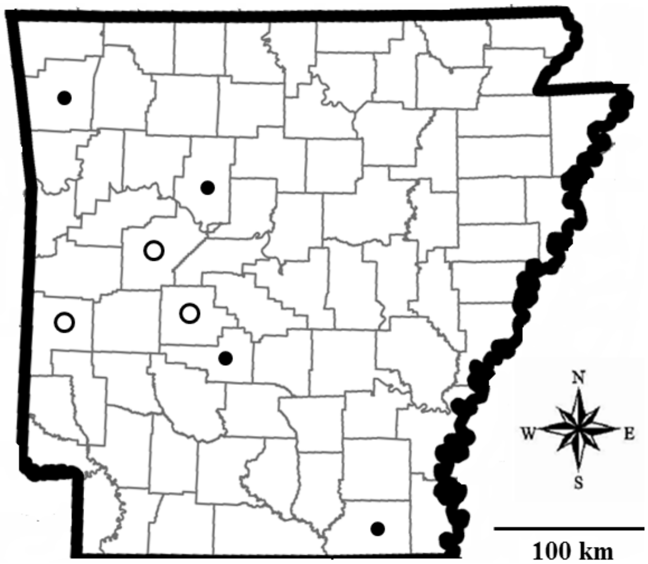

Figure 5. USNTC records of *Amblyomma maculatum* (solid dots) and *Dermacenter albipictus* (open dots) in AR.

***Dermacenter albipictus* (Packard) – winter tick.** This one-host tick parasitizes a variety of ungulates including cattle, horses and white-tailed deer and is widely distributed throughout North America (Strickland et al. 1976) but there are relatively few records from Arkansas. Lancaster et al. (1982a) used low daily oral doses of Ivermectin to control *D. albipictus* on calves in Arkansas.

USNTC records (Fig. 5): “Many” A ex *O. virginianus,* “eastern Arkansas,” Nov. 1937, H.H. Schwardt (RML 14818). 1F ex *O. virginianus,* Yell Co., 7 mi S. Bluffton, 18 Nov. 1950, JLL (RML 29195). 1F ex *E. caballus,* Polk Co., 2 Dec. 1950, Q.S. Dagenhart (RML 29196). 2M, 6F ex *O. virginianus,* Garland Co., Ouachita National Forest, 12-14 Nov. 1979, DAS (RML 109653, 109655). 3M, 4F ex *O. virginianus,* Yell Co., Ouachita National Forest, Nov. 1979, DAS (RML 109657, 109695–109696). 3F ex *O. virginianus,* Yell Co., 14-15 Nov. 1979, DAS (RML 109658, 109659).

***Dermacenter variabilis* (Say) – American dog tick.** This tick is widely distributed in the eastern United States and in some western states (Strickland et al. 1976). It probably occurs statewide in Arkansas but there are USNTC vouchers from only 19 counties (Fig. 6). Trout and Steelman (2010) documented *D. variabilis* from canines, felines and deer from several Arkansas counties mainly from March through August. Adults typically parasitize carnivores (especially domestic dogs), humans and other large mammals (Koch 1982). Immatures mainly parasitize rodents including cotton rats (*Sigmodon hispidis*), white-footed

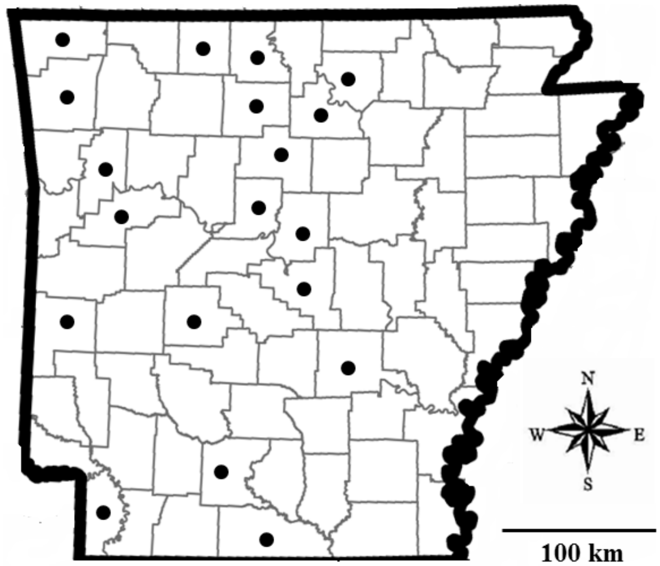

Figure 6. USNTC records of *Dermacenter variabilis* (solid dots) in AR.

mice (*Peromyscus leucopus*) and deer mice (*Peromyscus maniculatus*) (Strickland et al. 1976). Immature stages also parasitize rabbits and birds. McAllister et al. (2013a) reported 1 larval and 2 male *D. variabilis* on *S. niger* from Marion County, and a single southern flying squirrel (*Glaucomys volans*) from Union County harbored a larval American dog tick. Tumlison et al. (2015) reported *D. variabilis* from golden mice, *Ochrotomys nuttalli* from Union County, and white-footed mice, (*P. leucopus*), and a hispid cotton rat (*S. hispidis*) from Marion County.

This tick is the primary vector for the causative agents of RMSF and tularemia. Warner et al. (1996) documented 11 human cases of tick-associated RMSF in military personnel following field training exercises at Little Rock Air Force Base. Lancaster et al. (1982a) used oral doses of Ivermectin to control *D. variabilis* on calves in Arkansas.

USNTC records: Ex *C. familiaris* (13M, 5F) & *B. taurus* (1M), Boone Co., Harrison, 6–7 Jun. 1938, C.B. Philip & D. Conroy (RML 14191, 14192, 14196). 2A, host not stated, Boone Co., near Bergeman, 2 Aug. 1939, SJC (RML 16005). 21F ex *C. familiaris*, Boone Co., Harrison, 1 Aug. 1939, SJC (RML 16006). 2F ex *C. familiaris,* Marion Co., near Lead Hill, 5 Jul. 1939, SJC (RML 16653). 11A ex *C. familiaris*, Boone Co., Bergeman, 7 Jul. 1939, SJC (RML 16654). 22A ex *C. familiaris*, Boone Co., near Denver, 6 Jul. 1939, SJC (RML 16655, 16656). 1M, 1F, host & date not stated, Garland Co., H.H. Little (RML 19047, 19048). 1F ex *C. familiaris*, date not stated, Garland Co., H.H. Little (RML 19049). 1M, host not stated, Washington Co., near Fayetteville, 20 Jun. 1943, WJB (RML 20274). 1F ex *H. sapiens,* Washington Co., near Fayetteville, 10 Jul. 1943, WJB (RML 20291). 1F, host not stated, Union Co., near Marysville, Jul. 1943, WJB (RML 20292). 2M, 3F, host not stated, Ouachita Co., near Camp Albert Pike, Jul. 1943, WJB (RML 20293). 1M, host and date not stated, Logan Co., Mount Magazine, WJB (RML 21727). 8L ex *S. hispidus,* Boone Co., 1 mi S. Valley Springs, 20 Apr. 1947, H.B. Hungerford (RML 23734). 1F, drag cloth, Polk Co., 4 mi SW Mena, 3–4 Jul. 1947, J.M. Brennan (RML 23886). 1A ex *C. familiaris*, Polk Co., 1 mi SW Hatfield, 6 Jul. 1947, J.M. Brennan (RML 23892). 9A ex *C. familiaris* & unidentified host, Polk Co., 3.5 mi NW Hatfield, 7 Jul. 1947, J. M. Brennan (RML 23893, 23895). 1M, drag cloth, Polk Co., 5 mi NW Hatfield, 8 Jul. 1947, J.M. Brennan (RML 23899). 1M ex *F. catus*, Washington Co., 29 Apr. 1950, WJB (RML 27777). 1F ex *H. sapiens,* Conway Co., 14 Mar. 1950, WJB (RML 27782). 9M, 4F ex *E. caballus,* Washington Co., May 1950, WJB (RML 27784– 27785). 1F ex "rabbit," Searcy Co., 21 May 1950, WJB (RML 27789). 1M ex *C. familiaris*, Miller Co., 8 Apr. 1950, WJB (RML 27791). 1M, 1F ex *B. taurus*, Washington Co., 29 Apr. 1950, WJB (RML 27792). 1M ex *C. familiaris*, Izard Co., 8 Apr. 1950, WJB (RML 27794). 4M ex *C. familiaris*, Ouachita Co., 13 May 1950, WJB (RML 27797) 1F ex *C. familiaris,* Benton Co., 6 Jun. 1950, WJB (RML 27798). 5M, 6F ex *C. familiaris,* Washington Co., 21 May 1950, WJB (RML 27799). 2L ex *P. maniculatus,* Stone Co., Marcella, 22 Mar. 1948, FCW (RML 31804). 5N, 1L ex. *Peromyscus* sp., Franklin Co., Fly Gap Tower, 15 Jun. 1948, C.C. Sanborn (RML 31806). 1N, 1L ex *Neotoma floridana,* Stone Co., Marcella, 24 Mar. 1948, FCW (RML 31807). 2L ex *Reithrodontomys fulvescens,* Stone Co., Marcella, 23 Mar. 1948, C.C. Sanborn (RML 31809). 5N, 5L ex *S. floridanus*, Jefferson Co., Pine Bluff, 16 Mar. 1954, C.M. Clifford (RML 37564). 18A ex *C. familiaris,* Washington Co., Fayetteville, Jun. 1963, JLL (RML 38915). 38A, host and location not stated, 8 Jun. 1966, JLL (RML 46874). 1F ex *H. sapiens,* Faulkner Co., Conway, 18 Jun. 1910, A.H. Howell (RML 59461). 6M, 7F, drag cloth, Pulaski Co., Little Rock Air Force Base, 23 Jul. 1987, J. Goddard (RML 118549). 1M, drag cloth, Pulaski Co., Camp Robinson, 23 Jul. 1987, J. Goddard (RML 118551). 2M, 1F ex *Procyon lotor,* Van Buren Co., Sept. 1989, D.J. Richardson (RML 120864).

***Haemaphysalis leporispalustris* (Packard) – rabbit tick.** This tick is widely distributed across North

America (Cooley 1946). Adults mainly parasitize rabbits (*Sylvilagus* spp.) whereas immatures parasitize rabbits and a wide variety of ground-frequenting bird species (Cooley 1946, Lancaster 1973). It is an enzootic vector for the causative agents of tularemia and RMSF (Strickland et al. 1976).

USNTC records (Fig. 7): 41M, 2F, 9N ex *Sylvilagus* sp., Washington Co., Fayetteville, 5-6 Jun. 1938, C.B. Philip & D. Conroy (RML 14393, 14394, 14395, 14396). A (no. not stated) ex *Sylvilagus* sp., Boone Co., Harrison, 6-7 Jun. 1938, C.B. Philip & D. Conroy (RML 14398, 14399, 14814). 2N, host not stated, Washington Co., 11 Oct. & 3 Nov. 1941, H. Ross & C.O. Mohr (RML 21018, 23063). "several" A, N & L ex *S. floridanus,* Polk Co., 5 mi NW Hatfield, 8 July 1947, J.M. Brennan (RML 23897). 1F ex *F. catus,* Searcy Co., 21 Mar. 1950, WJB (RML 27779). 5F ex rabbit, Searcy Co., 21 May 1950, WJB (RML 27789). "numerous A, N & L" ex *S. floridanus,* Independence Co., 8 mi N. Batesville, 1 Apr. 1948, FCW (RML 31803). 6A ex swamp rabbit, *Sylvilagus aquaticus*, Independence Co., 8 mi N. Batesville, 1948, FCW (RML 31805). ~25A, N, & L ex *S. floridanus,* Stone Co., Marcella, 24 Mar. 1948, FCW (RML 31808, 31810). 1M ex *N. floridana,* Stone Co., Marcella, 25 Mar. 1948, FCW (RML 31811). ~30A, N & L ex *S. aquaticus*, Independence Co., 8 mi N. Batesville, 25 Mar. 1948, FCW (RML 31814). 4M, 4F, 2N, 2L ex *S. floridanus,* Independence Co., Batesville, 1 Apr. 1948, FCW (RML 89879).

***Ixodes baergi* Cooley and Kohls – no common name.** This tick was described from Washington County, Arkansas specimens by Cooley and Kohls (1942). It is a host-specific ectoparasite of cliff swallows (*Petrochelidon pyrrhonota*) and has been recorded from a few additional U.S. states as well as Arkansas (Baerg 1944, Larimore 1987, Keirans and Clifford 1978, Keirans et al. 1993, Durden and Keirans 1996b).

USNTC records (Fig. 7): 5M, 5F ex *P. pyrrhonota,* Washington Co., 21 Jun. 1941, WJB (RML 19248) (Type series). 52A ex *P. pyrrhonota*, Benton Co., Rogers, 1942, W.R. Horsfall (RML 23754). ~55A & N ex *P. pyrrhonota,* Benton Co., 8 & 20 Jun. 1944, JLL (RML 30466, 30603). 6M, 47F, 3L ex *P. pyrrhonota,* Benton Co., 19 Jul. 1942, 6 Jul. 1943 & 19 Apr. 1944, R.W. Larimore (RML 120942–120945) (returned to Illinois Natural History Survey Collection).

***Ixodes banksi* Bishopp – no common name.** This tick was described from specimens (15 females, 7 males) collected from a muskrat (*Ondatra zibethicus*) from Mammoth Spring, Fulton County, Arkansas (Bishopp 1911). However, it is typically a parasite of the American beaver (*Castor canadensis*) (Keirans and Clifford 1978, Durden and Keirans 1996b). No other records of this tick have been reported from Arkansas since the original description over a century ago.

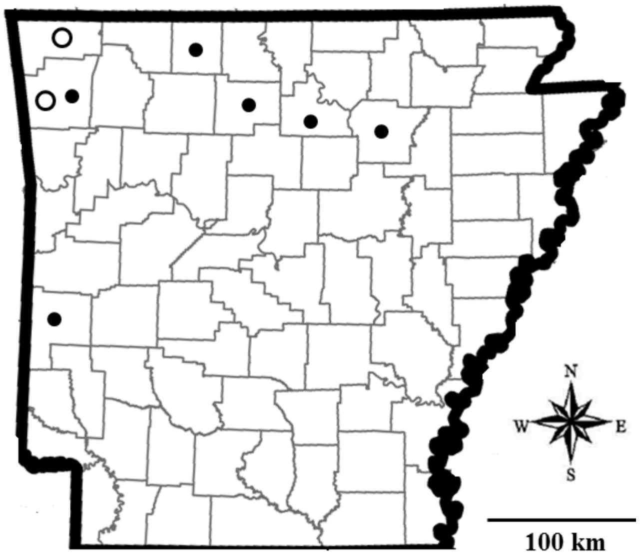

Figure 7. USNTC records of *Haemaphysalis leporispalustris* (solid dots) and *Ixodes baergi* (open dots) in AR.

USNTC records: (Fig. 8) Ex *O. zibethicus*, Fulton Co., Mammoth Spring, date not listed, N. Banks (RML 18727). 1F, 1N ex *O. zibethicus,* Fulton Co., Mammoth Spring, 4 Jun. 1910, coll. not stated (RML 49303) (Paratypes). 3E ex *O. zibethicus,* Fulton Co., Mammoth Spring, date not listed, N. Banks (RML 18727). 4F ex *O. zibethicus*, Fulton Co., Mammoth Spring, 14 Jun. 1910, A.H. Howell (RML 56789) (Type Series).

***Ixodes brunneus* Koch – no common name.** This is strictly a bird-feeding tick reported from a variety of avian hosts. In Arkansas, single specimens were reported previously from an eastern hermit thrush (*Catharus guttatus*) from northwestern Arkansas and slate-colored junco (*Junco hyemalis*) from North Little Rock by Lancaster (1973).

USNTC records: (Fig. 8) 1F ex *Junco* sp., Pulaski Co., North Little Rock, 12 Jan. 1943, R. Thomas (RML 19670). 1F ex *Zonotrichia albicollis,* North Little Rock, 10 Apr. 1943, R. Thomas (RML 20192). 3F ex *Cyanocitta cristata*, Pulaski Co., North Little Rock, 24 Feb. 1941, R. Thomas (RML 20196). 2F ex *J. hyemalis* & *Zonotrichia quercula,* Pulaski Co., North Little Rock, 1 Feb. 1944, R. Thomas (RML 20541–20542). 1F ex *Mimus polyglottus,* Pulaski Co., North Little

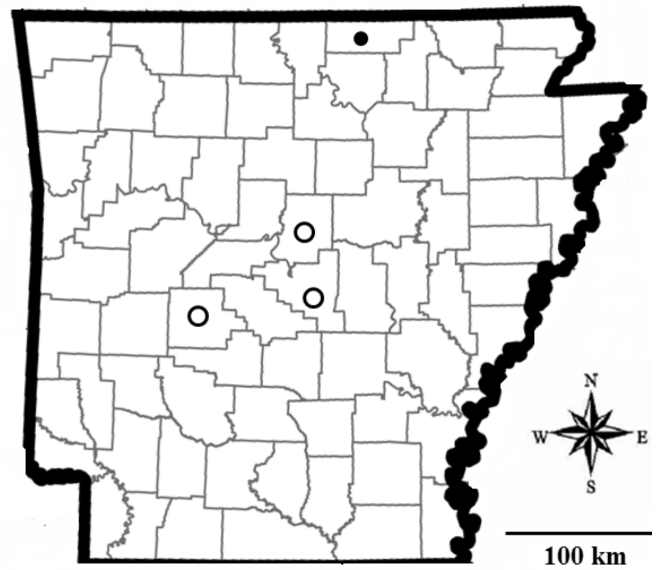

Figure 8. USNTC records of *Ixodes banksi* (solid dots) and *Ixodes brunneus* (open dots) in AR.

Rock, 18 Feb. 1944, R. Thomas (RML 20856). 2F ex *J. hyemalis*, Pulaski Co., North Little Rock, Feb. & Apr. 1944, R. Thomas (RML 20857, 20938). 5F ex *Z. albicollis*, Pulaski Co., North Little Rock, Apr. 1944, R. Thomas (RML 20935–20937, 21367). 1F ex *Bombycilla cedrorum*, Garland Co., Hot Springs, 27 Feb. 1958, S. O. Hill (RML 34615). 9F, 2N ex *Carpodacus purpureus* & *Cardinalis cardinalis*, Conway Co., Morrilton, 3 Feb. 1967, R. Thomas, (RML 47487). 2F ex *Junco* sp., Pulaski Co., Little Rock, Jan. 1941, R. Thomas (RML 66134).

***Ixodes cookei* Packard – no common name.** This tick infests a variety of medium-sized mammals, especially carnivores, including dogs, raccoons, skunks, and weasels (Keirans and Clifford 1978, Durden and Keirans 1996b). In Arkansas, it has previously been reported from the Virginia opossum (*Didelphis virginiana*), mink (*Mustela vison*), striped skunk (*Mephitis mephitis*), gray fox (*Urocyon cineargenteus*), raccoon (*Procyon lotor*), river otter (*L. canadensis*) and eastern woodrat (*N. floridana*) (Lancaster 1973, Richardson et al. 1994, Polechla 1996). Koch (1982) also reported *I. cookei* from domestic dogs in Arkansas. Powassan virus and *B. burgdorferi* have been detected in *I. cookei* (Durden and Keirans 1996b) but this tick is not considered to be a vector of the latter agent.

USNTC records: (Fig. 9) 1F ex *C. familiaris*, Boone Co., Harrison, 6 Jun. 1938, C.B. Philip & D. Conroy (RML 14191). 1F ex *C. familiaris*, Boone Co., Harrison, 1 Aug. 1939, SJC (RML 16006). 1F ex *C. familiaris*, Boone Co., near Denver, 6 Jul. 1939, SJC (RML 16655). 1F, host & coll. not stated, Washington Co., Corkscrew Cave, 12 Nov. 1938 (RML 18526). 4F ex *M. vison*, Prairie Co., Hazen, 10 Jan. 1948, C.L. Gates (RML 24728). 1N ex skunk, locality not stated, Fall 1949, WJB (RML 27372). 2F ex *L. canadensis*, locality not stated, 1985, P.J. Polechla (RML 117911). 7F, 19N, 13L ex *P. lotor*, Van Buren Co., 4 Nov. 1989 & 20 Jan. 1990, D. J. Richardson (RML 120865–120866).

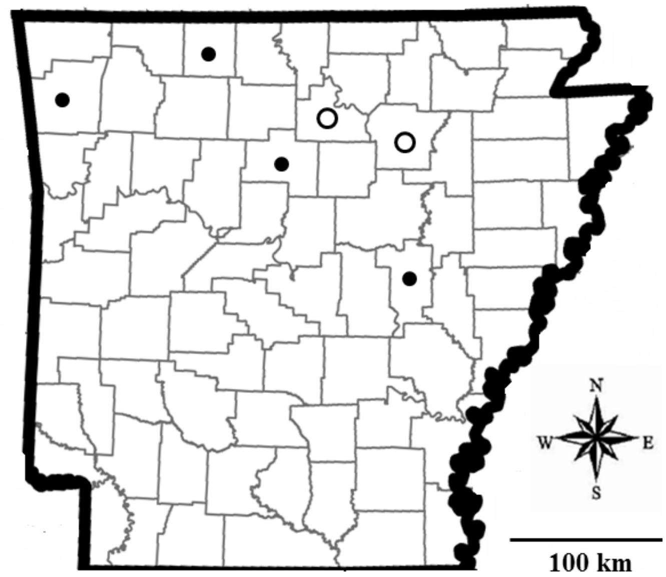

Figure 9. USNTC records of *Ixodes cookei* (solid dots) and *Ixodes dentatus* (open dots) in AR.

***Ixodes dentatus* Marx – no common name.** This tick is an important ectoparasite of rabbits (Keirans and Clifford 1978). However, immature stages also parasitize a variety of bird species (Durden and Keirans 1996b). The spirochete *Borrelia andersoni*, which is closely related to the agent of Lyme disease, has been detected in this tick (Durden and Keirans 1996b). Lancaster (1973) reported this tick from several rodents and also from swamp rabbit (*S. aquaticus*), Carolina wren (*Thryothorus ludovicianus*) and brown thrasher (*Toxostoma rufum*) in Arkansas.

USNTC records (Fig. 9)*:* 11M, 6F, 8N ex *S. floridanus*, Independence Co., 8 mi N. Batesville, 1 Apr. 1948, F.C. Wonder (RML 31803, 92264). 1M, 1N, 2L ex *S. floridanus*, Stone Co., Marcella, 24 Mar. 1948, F.C. Wonder (RML 31810).

***Ixodes marxi* Banks – no common name.** This tick typically parasitizes squirrels (Durden and Keirans 1996b). In Arkansas, it was documented previously from gray squirrels (*S. carolinensis*) by Lancaster

(1973). In addition, McAllister et al. (2013a) reported a single female *I. marxi* on *S. niger* from Marion County.

USNTC records (Fig. 10)*:* 4F ex *S. carolinensis,* Washington Co., near Fayetteville, 4 Dec. 1949, WJB (RML 27092). 1F ex squirrel, locality not stated, Fall 1949, WJB (RML 27373). 5F ex *S. niger,* Madison Co., locality not stated, 12 Oct. 1946, JLL (RML 33129).

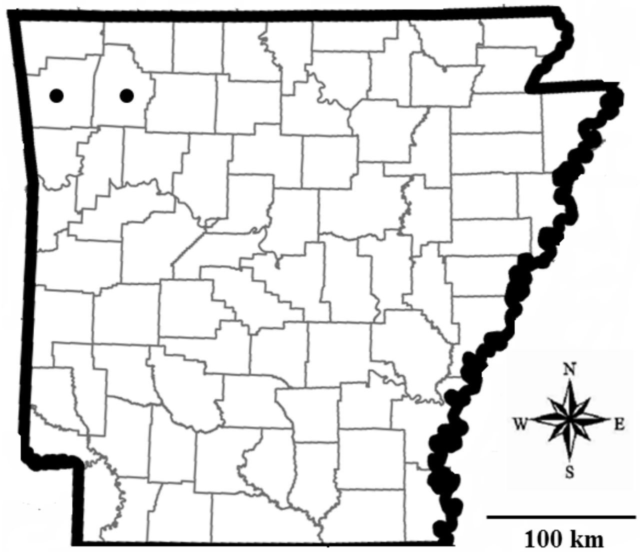

Figure 10. USNTC records of *Ixodes marxi* (solid dots) in AR.

***Ixodes scapularis* Say – blacklegged tick.** This is a common and widespread tick in Arkansas (Trout et al. 2009, Trout and Steelman 2010, Eisen et al. 2016) although USNTC vouchers are known from only 19 counties (Fig. 11). Eisen et al. (2016) reported *I. scapularis* to be established in 27 Arkansas counties and reported it from a further 25 Arkansas counties. Adults parasitize medium to large-sized mammals including ungulates, carnivores, lagomorphs and humans (Keirans and Clifford 1978, Koch 1982, Richardson et al. 1994, Keirans et al. 1996, Eisen et al. 2016) whereas immatures parasitize the same hosts plus a wide range of small mammals, birds and reptiles (Durden and Keirans 1996b, Keirans et al. 1996, Whalley 1999). Immature stages (both nymphs and larvae) are common on lizards in Arkansas including green anole (*Anolis carolinensis*), five-lined skink (*Plestiodon fasciatus*), broad-head skink (*Plestiodon laticeps*), prairie lizard (*Sceloporus consobrinus*) and ground skink (*Scincella lateralis*) (McAllister et al. 2013b, 2014). This tick is the most important vector in eastern North America of the causative agents of Lyme disease, human granulocytic anaplasmosis (HGA) (caused by *Anaplasma phagocytophilum*) and babesiosis (mainly caused by *Babesia microti*) (Durden and Keirans 1996b). It can also transmit other pathogens including deer tick virus, a variant of Powassan virus that causes Powassan encephalitis (Eisen et al. 2016). Simpson et al. (1993) and Gullo (1998) surveyed Arkansas ticks, mainly *I. scapularis,* for *B. burgdorferi.* Trout et al. (2009) studied the population genetics and phylogeography of *I. scapularis* parasitizing canines and deer in Arkansas. Trout-Fryxell et al. (2012) screened Arkansas ticks, canines and deer for borreliae.

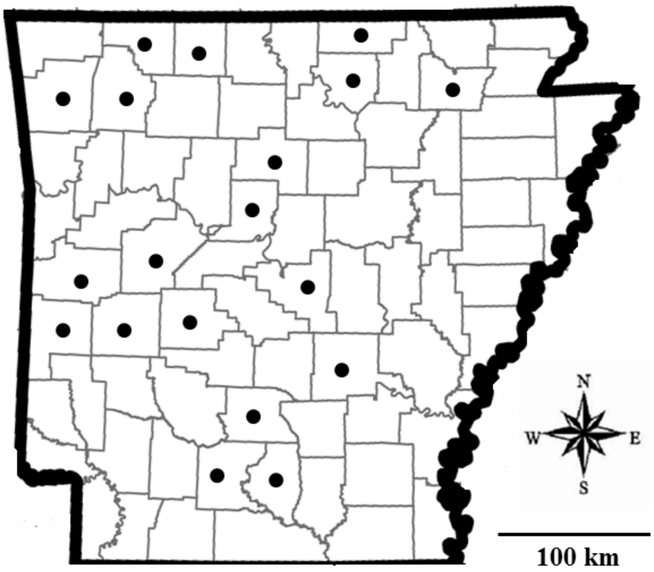

Figure 11. USNTC records of *Ixodes scapularis* (solid dots) in AR.

USNTC records: 2F ex *Lynx rufus,* locality not stated, 1937, H.H. Schwardt (RML 14815). "Many" A ex *O. virginianus,* "eastern Arkansas," Nov. 1937, H.H. Schwardt (RML 14818). 1F ex *C. familiaris,* Boone Co., Lead Hill, 14 Mar. 1939, SJC (RML 15506). 1M, 4F ex *C. familiaris* & *B. taurus,* Dallas Co., Sparkman, 3 Apr. 1939, SJC (RML 15516–15517). 1F ex *B. taurus,* Calhoun Co., Locust Bayou, 4 Apr. 1939, SJC (RML 15520). 1F ex *C. familiaris,* Conway Co., Morrilton, Mar. 1940, W. Dan (RML 17582). 1F ex *C. familiaris,* Pulaski Co., North Little Rock, 4 Feb. 1943, R. Thomas (RML 20193). 2M, 3F ex *C. familiaris* & 2M, 3F ex *O. virginianus* Madison Co., Huntsville, 20 Feb. 1944, WJB (RML 20760, 20854). 3F ex *C. familiaris,* Madison Co., Huntsville, Mar. 1944, WJB (RML 21023). 1M, 1F ex *B. taurus,* Garland Co., 20 Mar. 1946, R.L. Melton (RML 22342). 4F ex *B. taurus,* Boone Co., 1 mi S. Valley Springs, 19 Apr. 1947, H. B. Hungerford (RML 23739). 1N, drag cloth, Polk Co., 4 mi SW Mena, 3 Jul. 1947, J.M. Brennan (RML 23888). 2F ex *H. sapiens,* Polk Co., Hatfield, 29 Dec. 1947, J.P. Redman

(RML 246143). 1F ex *H. sapiens,* Carroll Co., Berryville, 12 Nov. 1949, WJB (RML 27181). Ex *C. familiaris* (2M, 8F) & *H. sapiens* (1M, 5F), early Fall 1949, locality not stated, WJB (RML 27367–27368). 1M ex *H. sapiens,* Washington Co., 23 Mar. 1949, WJB (RML 27369). 1F ex *B. taurus,* Izard Co., Fall 1949, WJB (RML 27370). 1F ex *F. catus,* Fulton Co., 23 Mar. 1949, WJB (RML 27371). 7M, 13F ex *H. sapiens, C. familiaris, E. caballus* & *B. taurus,* locality not stated, Fall 1949, WJB (RML 27374). 1F ex *C. familiaris,* Ouachita Co., 13 May 1950, WJB (RML 27797). 1M, 1F ex *U. cinereoargenteus,* Jefferson Co., Pine Bluff, 18 Nov. 1953, C.M. Clifford (RML 37562). 11F ex *C. familiaris,* Washington Co., Fayetteville, 10 Apr. 1964, JLL (RML 39575). 1M ex *B. taurus,* Montgomery Co., Mount Ida, 17 Nov. 1938, WJB (RML 58661). 1M, 1F (plus other specimen not listed?) ex *C. familiaris, E. caballus* & *B. taurus,* Lawrence Co., Mount Ida, 17 Nov. 1938, WJB (RML 66133). 2F ex *O. virginianus,* Scott Co., Waldron, 30 Oct. 1978, W. Montague (RML 105929). 10F ex *O. virginianus,* Ouachita National Forest, 16 & 30 Nov. 1978, W. Montague (RML 105970–105971). 2M, 8F ex *O. virginianus,* Garland Co., Ouachita National Forest, 12–14 Nov. 1979, DAS (RML 109653, 109654, 109655). 1M, 6F ex *O. virginianus,* Montgomery Co., Ouachita National Forest, 13 Nov. 1979, DAS (RML 109656). 7F ex *O. virginianus,* Yell Co., 14–15 Nov. 1979, DAS (RML 109658, 109659). 9M, 14F ex *O. virginianus,* Yell Co., Ouachita National Forest, Nov. 1979, DAS (RML 109657, 109695, 109696). 3M, 6F ex *O. virginianus,* Perry Co., Ouachita National Forest, Nov. 1978, DAS (RML 109694). 5M, 6F ex *O. virginianus,* Garland Co., Ouachita National Forest, Nov. 1978, DAS (RML 109697, 109698). 2N, 4L, hosts & localities not stated, 19 May 1977, M. Coan (RML 117509–117510). 2M, 1F ex *P. lotor,* Van Buren Co., 2 Mar. 1990, D.J. Richardson (RML 120867).

Ixodes texanus **Banks – no common name.** This tick parasitizes a variety of carnivores across much of North America (Keirans and Clifford 1978, Durden and Keirans 1996b) but the only Arkansas records are from raccoons (Richardson et al. 1994).

USNTC records (Fig. 12): 7N, 1L & 1F, 1N ex *P. lotor,* Van Buren Co., 4 Nov. 1989, 20 Jan. 1990 & 9 Apr. 1990, D.J. Richardson (RML 120866, 120868).

Ixodes woodi **Bishopp – no common name.** This tick mainly parasitizes woodrats, *Neotoma* spp. in various parts of North America (Durden and Keirans1996b). Although the record is almost 70 yr old, we document this tick from Arkansas for the first time. Additional collections of *N. floridana* from the state should increase the number of county records for *I. woodi*.

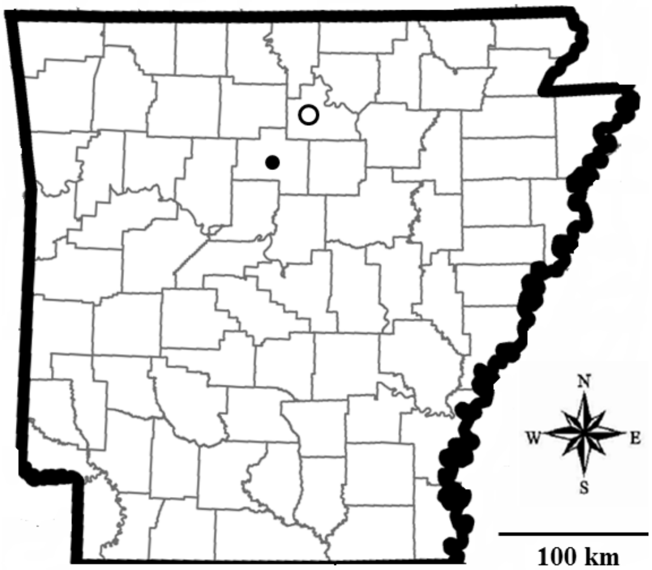

Figure 12. USNTC records of *Ixodes texanus* (solid dot) and *Ixodes woodi* (open dot) in AR.

USNTC record (Fig. 12): 1F, 4N, 5L ex *N. floridana,* Stone Co., Marcella, 24 Mar. 1948, FCW (RML 31812).

Rhipicephalus **(*Boophilus*) *annulatus*** **(Say) – cattle tick.** This non-native, invasive one-host tick was formerly widespread in Arkansas (Cooley 1946, Lancaster 1973) but it had been all but eliminated from the USA by 1943 as a result of the Cattle Fever Tick Eradication Program initiated by USDA in 1906 (Strickland et al. 1976). Nevertheless, this tick can still be recorded along the Texas-Mexico border especially on parasitized livestock being brought into the states (Lohmeyer et al. 2011). All active stages feed on ungulates, including bison, cattle, deer, horses, goats, mules, and sheep. This economically important tick is a vector of *Babesia bigemina* and *Anasplasma marginale,* the causative agents of bovine babesiosis (also referred to as Texas cattle fever, redwater fever and bovine piroplasmosis) and bovine anaplasmosis, respectively (Strickland et al. 1976).

Rhipicephalus sanguineus **(Latreille) – brown dog tick.** This non-native invasive tick is the most widely distributed tick in the world (Leeson 1951, Walker et al. 2000). In North America, all active stages typically feed on domestic dogs (Walker et al. 2000). Koch

(1982) reported *R. sanguineus* to be the most common tick parasitizing domestic dogs in northwestern Arkansas. Trout and Steelman (2010) also reported this tick to be a common ectoparasite of canines in the state. However, humans are also sometimes bitten. *Rhipicephalus sanguineus* can breed indoors often parasitizing dogs in large numbers and causing significant blood loss (Strickland et al. 1976). In the USA, this tick is the main vector of *Babesia canis*, a causative agent of canine babesiosis, and of *Ehrlichia canis*, a causative agent of canine ehrlichiosis (canine tropical pancytopenia) (Walker et al. 2000). Other pathogens or symbionts transmitted to dogs by *R. sanguineus* in North America include *R. rickettsii*, *Rickettsia rhipicephali* (a non-pathogenic SFGR), *Hepatozoon canis* (causative agent of canine hepatozoonosis), *Haemobartonella canis* (an epierythrocytic rickettsial parasite), *F. tularensis* and *Coxiella* sp. (Walker et al. 2000). This ectoparasite can also (rarely) cause tick paralysis in dogs (Walker et al. 2000). Recently, *R. sanguineus* has been shown to be a vector of *R. rickettsii* to humans in Arizona (Demma et al. 2005).

USNTC record: 1N ex *C. familiaris,* Pulaski Co., Little Rock, 17 Aug. 1945, WJB (RML 21973).

Discussion

We have provided a summation of the 19 ticks of Arkansas and note species that are vectors for disease agents. In addition, we report *I. woodi* in Arkansas for the first time. The county distribution of records for ticks in the state tends to show that the vast majority of records were obtained from various hosts in counties of the Interior Highlands (Ozarks and Ouachitas) (Fig. 1). Perhaps part of the reason for this distribution is the closer proximity of that region to the University of Arkansas, where most of the personnel who conducted previous tick research were employed. There are a moderate number of records in counties from the Gulf Coastal Plain; however, very few records are from far eastern Arkansas (Fig. 1). Additional collecting should be undertaken in those counties, particularly on Crowley's Ridge and in the Delta.

Acknowledgments

We thank Ms. Colleen R. Evans, Collections Manager at GSU, for making USNTC records and specimens of Arkansas ticks available for study. We dedicate this paper to the memory of Dr. J. L. "Jay" Lancaster, Jr. (1923-2016), Arkansas tick specialist extraordinaire, who passed away during the production of this review.

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Acanthocephala of Arkansas, Including New Host and Geographic Distribution Records from Fishes

C.T. McAllister[1*], D.J. Richardson[2], M.A. Barger[3], T.J. Fayton[4] and H.W. Robison[5]

[1]*Science and Mathematics Division, Eastern Oklahoma State College, Idabel, OK 74745*
[2]*Department of Biological Sciences, Quinnipiac University, Hamden, CT 06518*
[3]*Department of Natural Science, Peru State College, Peru, NE 68421*
[4] *Gulf Coast Research Laboratory, University of Southern Mississippi, Ocean Springs, MS 39564*
[5]*Department of Biological Sciences, Southern Arkansas University, Magnolia, AR 71754-9354*

*Correspondence: cmcallister@se.edu

Running Title: Acanthocephalans of Arkansas

Abstract

Little is known about the spiny- or thorny-headed worms (Phylum Acanthocephala) of Arkansas and there are no summaries on the acanthocephalans of the state. Here, we provide a checklist of the 22 acanthocephalans that occur in Arkansas' vertebrates based on previously published records and new data presented herein. In addition, we document a new state record as well as 13 new host records for some fish acanthocephalans.

Introduction

The phylum Acanthocephala includes at least 4 classes, 10 orders, 26 families, and about 1,300 species (Amin 2013). Adults are highly specialized, dioecious parasites of the intestinal tract of a variety of vertebrates. As adults acanthocephalans reside exclusively in the vertebrate small intestine. They have an indirect life cycle involving at least 2 hosts, either an aquatic intermediate host (Amphipoda, Copepoda, Isopoda, and Ostracoda) or terrestrial intermediate host, including insects, crustaceans and myriapods. Fishes, amphibians, reptiles, birds, and mammals serve as definitive hosts.

The purpose of this report is 2-fold: (1) provide a checklist of the acanthocephalans that occur in Arkansas based on previously published records, and (2) document new host and distributional records of some acanthocephalans from fishes.

Methods

Between April 2014 and July 2015, we collected fishes with backpack electrofishers, dipnets and seines. Fish were placed in habitat water and necropsied within 24 hr. We followed accepted guidelines for the use of fish in research (AFS 2004). Specimens were overdosed with a concentrated Chloretone (chlorobutanol) solution and measured for total length (TL). A mid–ventral incision from anus up to the level of the stomach was made to expose the gastrointestinal tract and other internal viscera (including gallbladder) which was removed and placed in a Petri dish containing 0.6% w/v saline. Acanthocephalans were transferred to Petri dishes containing distilled water overnight to completely evert their proboscides. They were then placed in 70–95% v/v DNA-grade ethanol, stained with acetocarmine and mounted entire with Canada balsam or Damar gum. Voucher specimens were deposited in the Harold W. Manter Laboratory of Parasitology Parasite Collection (HWML), Division of Parasitology, University of Nebraska-Lincoln, State Museum. Host voucher specimens were deposited in the Henderson State University Museum (HSU), Arkadelphia, Arkansas. Prevalence, mean intensity, and range of infection are provided in accordance with terminology given in Bush et al. (1997).

We also examined the scientific literature for previous information on reports of acanthocephalans from Arkansas. Reports of unidentified acanthocephalan cystacanths from various Arkansas vertebrate hosts, were not included herein. We follow Amin's (2013) classification of the Acanthocephala.

The annotated list of data for fish hosts harboring acanthocephalans is as follows: host and TL (mean ± 1SD range, when available), prevalence, intensity (mean ± 1SD range, when available), collection site, collection date, HWML accession number.

Results and Discussion

The following species of acanthocephalans have been previously reported from vertebrate hosts in Arkansas:

ACANTHOCEPHALA OF ACTINOPTERYGII

Eoacanthocephala: Neoechinorhynchida: Neoechinorhynchidae

Neoechinorhynchus sp. – *Aphredoderus sayanus*, Pirate Perch (McAllister et al. 2014a); *Moxostoma duquesnei*, Black Redhorse (McAllister et al. 2015a).

Neoechinorhynchus cylindratus (Van Cleave, 1911) Van Cleave, 1919 – *Micropterus dolomieu*, Smallmouth Bass, *Micropterus punctulatus*, Spotted Bass, *Micropterus salmoides*, Largemouth Bass (Becker et al. 1966); *Ameiurus natalis*, Yellow Bullhead, *Lepomis macrochirus*, Bluegill, *M. punctulatus*, *M. salmoides* (Becker and Houghton 1969); *Pomoxis annularis*, White Crappie, *L. macrochirus*, *M. salmoides*, *M. punctulatus*, *Lepomis gularis*, Warmouth (Becker and Cloutman 1975); *M. salmoides, L. macrochirus* (Cloutman 1975). At least 7 species of ostracods serve as the first intermediate host, with smaller non-game fishes as paratenic hosts.

Neoechinorhynchus prolixus Van Cleave and Timmons, 1952. *Carpiodes velifer*, Highfin Carpsucker (McAllister et al. 2015a).

Paulisentis sp. – *Campostoma anomalum*, Central Stoneroller (McAllister et al. 2015a).

Paleoacanthocephala: Echinorhynchida: Echinorhynchidae

Acanthocephalus tahlequahensis Oetinger and Buckner, 1976 – *Cottus carolinae*, Banded Sculpin (McAllister et al. 2014d); *Ambloplites ariommus*, Shadow Bass, *Noturus exilis*, Slender Madtom (McAllister et al. 2015a).

Heteroacanthocephalidae

Aspersentis sp. – *A. sayanus* (McAllister and Amin 2008).

Pomphorhynchidae

Pomphorhynchus lucyi Williams and Rodgers, 1984 – *A. sayanus* (McAllister and Amin 2008).

Illiosentidae

Leptorhynchoides sp. – *A. sayanus* (McAllister et al. 2014a).

Leptorhynchoides thecatus (Linton, 1891) Kostylev, 1924 – *M. salmoides* (Becker et al. 1966, Becker and Houghton 1969, Becker and Cloutman 1975). Note: Classification of this common parasite was recently revised by Steinauer and Nickol (2015); previous records from fishes need to be re-examined.

ACANTHOCEPHALANS OF AMPHIBIA

Fessisentidae

Fessisentis vancleavei – *Eurycea tynerensis*, Oklahoma salamander (Buckner and Nickol 1978, McAllister et al. 1995, 2014c).

ACANTHOCEPHALANS OF REPTILIA

Neoechinorhynchidae

Neoechinorhynchus chrysemydis Cable and Hopp, 1954 – *Trachemys scripta elegans*, red-eared slider (Cable and Fisher 1957, Fisher 1960, Rosen and Marquardt 1978).

Neoechinorhynchus emydis (Leidy, 1851) Van Cleave, 1916 – *Graptemys geographica*, common map turtle (McAllister et al. 2014b).

Neoechinorhynchus emyditoides Fisher, 1960 – *T. s. elegans* (Cable and Fisher 1957, Fisher 1960, Rosen and Marquardt 1978, Barger 2004).

Neoechinorhynchus pseudemydis Cable and Hopp, 1954 – *T. s. elegans* (Cable and Fisher 1957, Fisher 1960, Rosen and Marquardt 1978, Barger 2004).

Neoechinorhynchus stunkardi Cable and Fisher, 1961 – *T. s. elegans* (Rosen and Marquardt 1978).

Pomphorhynchidae

Pomphorhynchus bulbicolli Linkins in Van Cleave, 1919 – *Nerodia sipedon pleuralis*, Midland water snake (McAllister et al. 2015b). The presence of *P. bulbocolli* in this snake is considered to be an artifact of a piscivorous diet and the host should be considered accidental.

ACANTHOCEPHALA OF AVES

Paleoacanthocephala: Polymorphida: Centrorhynchidae

Centrorhynchus conspectus Van Cleave and Pratt, 1940 – *Bubo virginianus*, great horned owl (Richardson and Nickol 1995).

ACANTHOCEPHALA OF MAMMALIA

Archiacanthocephala: Moniliformida: Moniliformidae

Moniliformis clarkii (Ward, 1917) Chandler, 1921 – *Sciurus carolinensis*, eastern gray squirrel (Singleton et al. 1993).

Oligachanthorhynchida: Oligacanthorhynchidae

Macracanthorhynchus ingens (von Linstow, 1879) Travassos, 1917 – *Procyon lotor*, raccoon (Richardson et al. 1992, Richardson 2014).

Oligacanthorhynchus microcephalus (Rudolphi, 1819) Schmidt, 1972 – (syn. *O. tortuosa*) *Didelphis virginiana*, Virginia opossum (Richardson 1993, Richardson and Barnawell 1995, Richardson et al. 2014).

Palaeacanthocephala: Polymorphida: Centrorhynchidae

Centrorhynchus conspectus Van Cleave and Pratt, 1940. – *D. virginiana* (Richardson 1993); *P. lotor* (Richardson et al. 1992).

Plagiorhynchidae

Plagiorhynchus cylindraceus (Goeze, 1782) Schmidt and Kuntz, 1966. – *D. virginiana* (Ellis et al. 1999).

NEW HOST AND GEOGRAPHIC RECORDS FOR ACANTHOCEPHALANS FROM ACTINOPTERYGII

Counties where acanthocephalans were collected from fishes are presented in Fig. 1. All hosts were taken from the Arkansas, Ouachita and White river drainages. Our findings are documented as new host records for each acanthocephalan listed below.

Pomphyrhynchus bulbocolli Linkins in Van Cleave, 1919

Campostoma spadiceum, 1 male, 1 female, Garland Co., Walnut Creek (34.533874°N, 93.371049°W), 8 Jun. 2015. HWML 101937.

Luxilus pilsbyri, 110 mm TL, 3 specimens, Izard Co., Calico Creek (36.122557°N, 92.143797°W), 7 Jul. 2015. HWML 101941.

Although this acanthocephalan is widely-distributed in North American freshwater fishes (Amin 1987, Hoffman 1999), this is the first report of *P. bulbocolli* from Arkansas fishes.

Neoechinorhynchus prolixus Van Cleave and Timmons, 1952

Carpiodes cyprinus, Marion Co., Crooked Creek (36.244433°N, 92.716531°W), 23 Jul. 2014, HWML 75374. McAllister et al. (2015a) previously reported *N. prolixus* from *C. velifer* from Arkansas.

Acanthocephalus dirus (Van Cleave, 1931) Van Cleave and Townsend, 1936

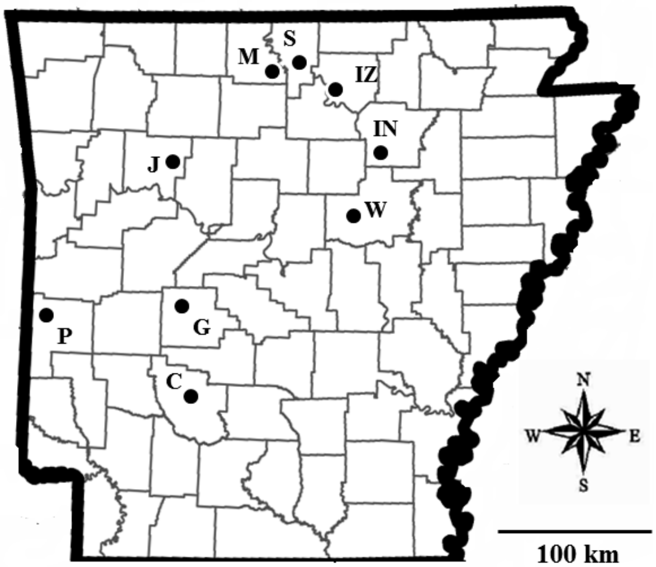

Figure 1. Nine Arkansas counties containing streams where fishes harbored acanthocephalans. Abbreviations: C (Clark), G (Garland), IN (Independence), IZ (Izard), J (Johnson), Marion (M), P (Polk), S (Sharp), W (White).

Etheostoma artesiae, 5 gravid females. Clark Co., Mill Creek off St. Hwy 7 (34.033599°N, 92.935703°W), 9 Apr. 2015. HWML 101943.

Etheostoma whipplei, 74 mm TL, 2 females, 1 juvenile, Johnson Co., Washita Creek (35.654197°N, 93.593527°W), 7 Jun. 2015. HWML 101938.

Lepomis cyanellus, 1 male, 2 gravid females, White Co., Gin Creek in Searcy (35.2511°N, 91.716288°W), 4 Apr. 2014. HWML 101947.

Luxilus zonatus, 1 female, Sharp Co., N Big Creek at St. Hwy 354 (36.157657°N, 91.5141°W), 8 Jul. 2015. HWML 101981. This is the first report of any helminth from this host.

Acanthocephalus dirus has the widest geographical and host distribution and is found in at least 16 families of fish mostly in the Mississippi River drainage in 13 states in the USA (Amin 1985). We document 4 new host records and document *A. dirus* for the first time from Arkansas.

Acanthocephalus tahlequahensis Oetinger and Buckner, 1976

Etheostoma radiosum, 2 males, Garland Co., Walnut Creek (34.533874°N, 93.371049°W), 26 Nov. 2014, HWML 101949; 1 male, 2 males, Garland Co., Bear Creek at Bear (34.534784°N, 93.285969°W), 2 specimens, 63 mm TL, 26 Nov. 2014, 22 May 2015, HWML 101934, 101950; Polk Co., Carter Creek (34.543342°N, 94.165758°W), 22 May 2015, HWML 101935; 1 female, Garland Co., Middle Branch Gulpha Creek (34.510095°N, 93.008682°W), 8 Jun. 2015. Not deposited.

Lepomis cyanellus, 1 male, Polk Co., Carter Creek (34.543342°N, 94.165758°W), 22 May 2015. HWML 101936.

McAllister et al. (2014d) previously reported *A. tahlequahensis* in Arkansas from *C. carolinae*. This species was described from adjacent Oklahoma in the Illinois River drainage and reported from Sunburst Darter (*Etheostoma mihileze*), Orangethroat Darter (*Etheostoma spectabile*), Redspot Chub (*Nocomis asper*), and Cardinal Shiner (*Notropis cardinalis*) (Oetinger and Buckner 1976). McAllister et al. (2015a) extended the host range in fishes of the Centrarchidae and Ictaluridae and here we add 2 new hosts and a new river drainage (Ouachita).

Neoechinorhynchus sp.

Etheostoma spectabile, 1 male, White Co., Dennard Creek (35.257397°N, 91.744696°W), 4 Apr. 2015. HWML 101948.

Esox americanus, 1 juvenile, Polk Co., Abernathy Spring (34.468162°N, 93.947976°W), 23 May 2015. HWML 101939.

Hypentelium nigricans, 159 mm TL, 1 juvenile, Marion Co., Crooked Creek (36.244433°N, 92.716531°W), 23 Jul. 2014. Not deposited.

Moxostoma carinatum, 325mm TL, 1 juvenile female, Independence Co., White River at Batesville (35.756648°N, 91.638512°W), 5 Apr. 2014. HWML 101946.

Since a male and 3 juveniles were found in these 4 hosts, no specific identification was possible; however, we document 4 new host records for the genus.

In summary, we provide a checklist of the 22 acanthocephalans now known from Arkansas as well providing 13 new host records and a new state record (*A. dirus*) for fish acanthocephalans. Additional surveys, particularly of birds along the eastern corridor and southern tier of counties, and of fishes from other Arkansas river drainages, will undoubtedly increase our knowledge of these parasites.

Acknowledgments

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Lithostratigraphic Succession and Depositional Dynamics of the Lower Mississippian, Southern Ozarks, Northern Arkansas and Adjacent Areas

F. McFarlin

Department of Geosciences, University of Arkansas, Fayetteville, Arkansas

Correspondence: fdmcfarl@email.uark.edu

Running Title: Lithostratigraphic and Depositional Dynamics of the Lower Mississippian Succession

Abstract

The Lower Mississippian interval comprises a single, third-order, eustatic cycle subdivided lithostratigraphically into the St. Joe Limestone (Hopkins 1893) and overlying Boone Formation (Branner 1891, Simonds 1891) with type areas in northern Arkansas. Coeval, homotaxial limestones occur in adjacent southwestern Missouri and northeastern Oklahoma, but neither Arkansas name is applied. To eliminate this “state line fault,” Missouri formation names for the St. Joe interval are recognized in Arkansas as members (ascending order): Bachelor, Compton, Northview, Pierson. The Boone interval in Missouri is represented by the (ascending order): Reeds Spring, Elsey, Burlington-Keokuk undifferentiated, but utilization of those names in Arkansas is problematic. Chert development and characteristics associated with the Boone Formation in northern Arkansas have not been applied to the equivalent succession in Missouri. Consequently, in northern Arkansas, the Boone Formation is subdivided into informal lower and upper members based on chert development: lower with black to gray, penecontemporaneous chert; upper with white to light gray, later diagenetic chert. In adjacent northeastern Oklahoma, the nomenclature is a mixture of the Arkansas and Missouri names, but chert development is not used lithostratigraphically. The St. Joe Limestone rests unconformably on the Chattanooga Shale (Upper Devonian-Lower Mississippian) or older units marking the initial transgression of the Kaskaskian II Cycle (Vail et al. 1977). Thin-bedded, St. Joe crinozoan packstones represent bioclastic sediment and carbonate mud transported from its origin on the Burlington Platform (now Missouri), and down the adjacent northern Arkansas ramp in a lobate manner. Distal limestones are condensed and replaced by shale beyond the ramp. A brief drop in sea level represented by the terrigenous Northview Member, was followed by continued transgression through Pierson deposition, reaching maximum flooding without a break in the lower Boone (=Reeds Spring) represented by calcisiltites and penecontemporaneous chert. Highstand and regression are recorded in the upper Boone as rapidly deposited crinoidal packstones and grainstones with later diagenetic chert replacement.

Introduction

The Lower Mississippian succession is the thickest post-Ordovician, pre-Middle Pennsylvanian interval deposited across the tri-state area of northern Arkansas, southern Missouri, and northeastern Missouri. Lithostratigraphic nomenclature for this predominantly limestone succession has been applied inconsistently, while chert development, typical of the upper portion of the interval, has been ignored for the most part. In Arkansas, the oldest valid names applied to these strata are the St. Joe Limestone (Hopkins 1893) and overlying Boone Formation (Branner 1891, Simonds 1891) with type areas in northern Arkansas. The St. Joe Limestone rests unconformably on the Chattanooga Shale (Upper Devonian-Lower Mississippian) or older units marking initial transgression. The component carbonates were all produced on the Burlington Platform (now mostly Missouri) (Lane, 1978), and transported down the adjacent northern Arkansas ramp in a lobate manner. Initial deposition was condensed, followed by maximum flooding that occurred in the lower Boone Formation followed by highstand and regression recorded in the upper Boone as the rate of deposition increased.

Geologic Setting

The tri-state region of the southern Ozarks includes portions of northwestern Arkansas, southwestern Missouri, and northeastern Oklahoma exposing Paleozoic strata at the surface. This area includes portions of three broader geologic provinces: the Ozark

Dome and Arkoma Basin of northwestern Arkansas, and the Cherokee Platform in northeastern Oklahoma (Fig. 1). The south flank of the Ozark Dome comprises three plateau surfaces: Salem, Springfield and Boston Mountains, capped by Lower Ordovician, Lower Mississippian and Middle Pennsylvanian strata respectively (Fig. 1).

The Ozark Dome is a broad, asymmetrical, cratonic uplift cored by Precambrian granite and rhyolite exposed in the St. Francois Mountains region of southeastern Missouri (Fig. 1). The Paleozoic sedimentary record surrounding the core is dominated by thick carbonate intervals with subordinate terrigenous clastics punctuated by unconformities reflecting occasional domal uplifts. The Arkoma Basin forms the southern margin of the Ozark Dome as a foreland basin that formed in response to the Ouachita Orogeny beginning in the Middle Pennsylvanian. The western margin of the Ozark Dome is continuous with the Cherokee Platform in eastern Oklahoma that reflects a cratonic setting with a transgressive-regressive history of deposition by epeiric seas, but preserves little evidence of Ozark Dome diastrophism.

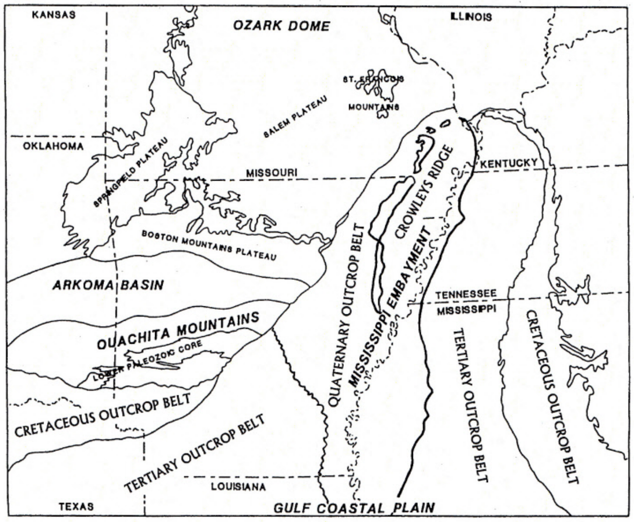

Fig. 1. Geologic Provinces of Arkansas and Adjacent Areas, Southern Midcontinent (modified from Manger, et al. 1988).

Sequence History

The Kaskaskia Sequence of the North American midcontinent essentially encompasses the Devonian and Mississippian Periods (Sloss 1963, 1982, Vail et al. 1977). Later, Sloss (1982) subdivided the Kaskaskia sequence into two second-order sequences: Kaskaskia I - Middle Devonian through the Lower Mississippian Kinderhookian Series, and Kaskaskia II – Osagean through the upper Chesterian Series. Subsequent usage has restricted the Kaskaskia I to the Devonian, and Kaskaskia II to the Mississippian (Vail et al. 1977; Ross and Ross 1987). The maximum flooding events of the first and second order Kaskaskian cycles occurred at about the Kinderhookian-Osagean boundary. The Kaskaskia II second order cycle encompasses two third-order cycles. The maximum flooding event of the lower Kaskaskia II third-order cycle also occurs at about the Kinderhookian-Osagean boundary (Ross and Ross 1987, Fig. 2). The lower Kaskaskia II third-order cycle may comprise as many as five fourth-order cycles (Ross and Ross 1987). Type 1 unconformities, produced when sea level drops below the edge of the continental shelf (Vail et al. 1977), mark the coeval first through third order cycle boundaries, and serve as the basis for the differentiation of the Kaskaskia I and II cycles. In the southern Ozarks, the third-order cycle comprising the St. Joe – Boone interval (Lower Mississippian) rests unconformably on the Chattanooga Shale (Upper Devonian-Lower Mississippian) or older units marking

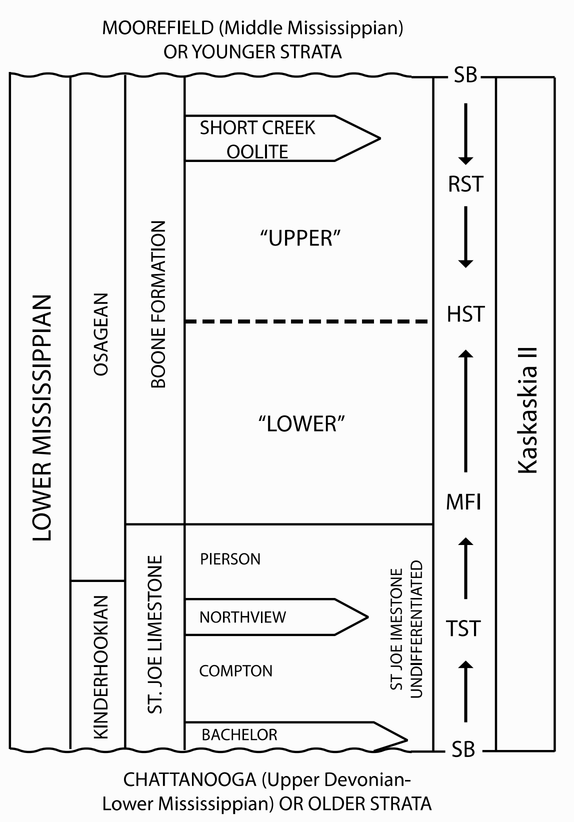

Fig. 2. Lithostratigraphy and Sequence History of the Lower Mississippian Interval, Southern Ozark Region, Northern Arkansas (modified from Manger and Shelby 2000).

the initial transgression of the Kaskaskian II Cycle (Fig. 2). The regressive phase of the Kaskaskia II cycle at the top of the Boone Formation produced a Type 1 unconformity overlain by Meramecian or younger strata in the tri-state region (Fig. 2).

Lithostratigraphy

The lithostratigraphic nomenclature for the Lower Mississippian succession in the tri-state area of northern Arkansas, southwestern Missouri, and northeastern Oklahoma have traditionally recognized a chert-free limestone interval succeeded by a chert-bearing limestone interval (= St. Joe-Boone). However, application of lithostratigraphic nomenclature is inconsistent, making the understanding of St. Joe-Boone interval difficult.

St. Joe Limestone – The St. Joe Limestone was proposed by Hopkins (1893) as the basal, chert-free member of the Boone Formation for railroad cut exposures in the vicinity of St. Joe, Searcy County, Arkansas, but no type locality was designated. Historically, the interval was regarded as a formation (Cline 1934, Kaiser 1950), and a group (Beveridge and Clark 1952, Huffman, 1958), but the Arkansas Geological Survey continues usage as a member, even though the St. Joe was mapped as a discrete interval on the first Geologic Map of Arkansas (Miser and Stose 1929). Thompson and Fellows (1970) proposed a primary reference section at an abandoned quarry along the abandoned St. Louis-North Arkansas railroad, two miles northwest of St. Joe, Searcy County, Arkansas.

The St. Joe Limestone represents the base of the Mississippian interval in northern Arkansas and northeastern Oklahoma, however in adjacent southwestern Missouri, the name has been abandoned. Instead, the interval in Missouri has been subdivided into the Bachelor, Compton, Northview and Pierson Formations (in ascending order) (Thompson and Fellows 1970, Thompson 1986). Although condensed, the southwestern Missouri lithostratigraphic divisions can be recognized across most of the Lower Mississippian outcrop belt in Arkansas, but nomenclaturally, there is a significant “state-line fault” between northern Arkansas and southwestern Missouri. To clarify regional relationships, the St. Joe should be elevated to formational rank with the Missouri units as members (Manger and Shanks 1977, Manger, Shelby, and Farris 1988, Manger and Shelby 2000).

Along the Mississippian outcrop belt in northern Arkansas, the St. Joe thins and condenses to the east, represented by only 3ft 8in at Walls Ferry, Independence County, yet containing a Kinderhookian-Osagean boundary based on conodonts (Thompson and Fellows 1970, Manger et al. 1988). It also pinches out down-ramp and cannot be identified in the subsurface south of the latitude of Washington-Crawford County line (Shelby 1986, Manger and Shelby 2000). Within the interval, both the Bachelor and Northview also pinch-out eastward along the outcrop belt and into the subsurface (Shelby 1986, Manger and Shelby, 2000). The base of the Middle Kinderhookian Bachelor Member is an erosional disconformity. Where it succeeds the Chattanooga Shale, it occurs as green, calcareous shale, while it is an orthoquartzitic sandstone, commonly with a gravel fraction of phosphate-replaced limestone, or occasionally a sandstone-shale couplet, when overlying older strata. The Northview represents a green, calcareous siltstone and shale that briefly interrupted St. Joe limestone deposition, due to a relative drop in sea level. The Kinderhookian-Osagean boundary based on conodonts occurs at the Northview-Pierson contact or within the first foot of the Pierson (Manger et al. 1988). Where the Northview is absent, the Compton and Pierson are indistinguishable, and the St. Joe is undifferentiated (Fig. 3). In northeastern Oklahoma, the St. Joe is accorded group status, and the Missouri formations, except the Bachelor, can be recognized (Huffman 1958). As in Arkansas, where the Bachelor and Northview are absent, the St. Joe is undifferentiated.

Boone Formation – The Boone Formation is the oldest valid formation name applied to the Osagean (Lower Mississippian) interval succeeding the St. Joe in northern Arkansas (Branner 1891, Simonds 1891). The name is credited to Branner by page priority, and is taken from Boone County, Arkansas, although no type section has been designated (Wilmarth 1938). As defined, the Boone Formation is a chert-bearing, crinozoan packstone-wackestone interval, reaching 300-350 feet, and forming most of the Springfield Plateau. In southwestern Missouri, the equivalent interval is divided into formations designated (ascending order): the Reeds Spring, Elsey, Burlington-Keokuk undifferentiated (Thompson 1986). Although chert-bearing, that lithologic characteristic is not utilized in recognizing those lithostratigraphic divisions. Deposition of the Boone interval was significantly faster than that of the St. Joe, which has diluted conodont occurrences making biostratigraphic correlation to southern Missouri difficult and lithostratigraphic assignment problematic. Consequently the name Boone is retained in Arkansas, but the

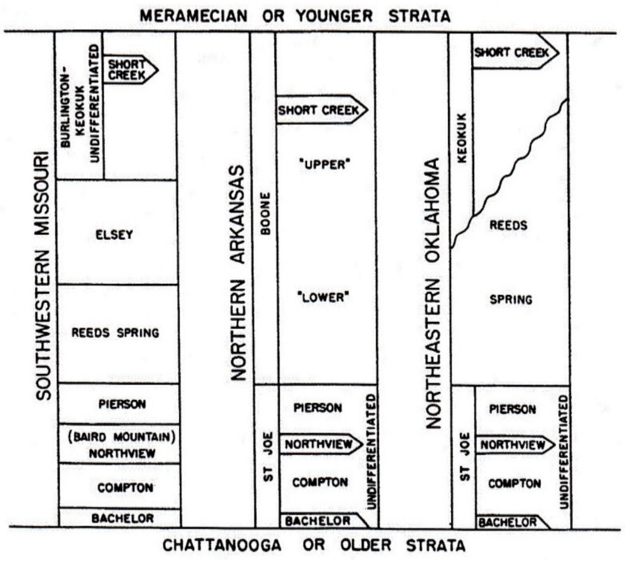

Fig. 3. Lower Mississippian Lithostratigraphic Nomenclature, Tri-State Region, Southern Ozarks (from Manger and Thompson 1982).

interval has been divided only informally into lower and upper members based on carbonate texture and chert development (*e.g.* Manger and Shelby 2000). The lower Boone interval was deposited below effective wave-base and is characterized by calcisiltites, and penecontemporaneous chert - dark, nodular, poorly bedded chert that disrupts bedding, and exhibits compaction features, indicating deposition prior to lithification. The upper Boone limestones were deposited within effective wave-base, and exhibit a framework of bioclastic grains of sand to gravel size, usually crinozoan detritus. The upper Boone is characterized by later diagenetic chert - white-light gray, selectively replacing the finer portions of the component limestones along the bedding planes as a groundwater phenomenon producing an apparently coeval, interbedded limestone-chert succession.

In northeastern Oklahoma, Huffman (1958), based on fossil occurrences, proposed an unconformable relationship without discussion in the Lower Mississippian succession. He assigned an interval of thinly, interbedded dark chert and fine-grained limestone to the Reeds Spring, succeeded by massive crinoidal limestone with mostly white to buff fossiliferous chert, that he assigned to the Keokuk (Huffman 1958). Since he could not recognize the Elsey or Burlington biostratigraphically, he assumed that there was an unconformity in the Osagean portion of the section (Fig. 4). As discussed in the sequence history section, the position of Huffman's unconformity would correspond to the Lower Mississippian maximum flooding-highstand interval, an unlikely place for a regional unconformity.

Oddly, the Short Creek Oolite (Smith and Siebenthal 1907), with a type section in Cherokee County, southeastern Kansas, is a formally named member recognized across the tri-state area, including the Boone Formation in northern Arkansas (McFarland 2004). This distinctive unit, usually thin, but reaching over 25 feet, is also interpreted as a down-ramp grain flow, rather than oolite shoal, that developed during the regressive phase of Boone deposition (Lisle 1984). Few Boone exposures preserve the Short Creek, suggesting brief, localized development of oolite shoals that were destroyed and the ooliths dispersed during the Boone regression.

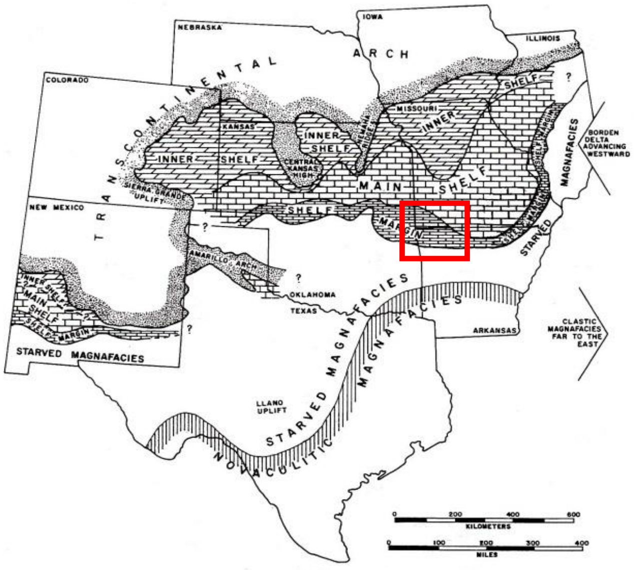

Fig. 4. Osagean Paleogeography and Lithofacies of the Southern Portion of the North American Craton, Burlington Shelf (modified from Lane 1978). This study area in red box.

Depositional Dynamics

The entire Lower Mississippian succession preserved in northern Arkansas represents transported carbonates that originated as the result of biological activity: green algae produced the carbonate mud, while the associated sand and gravel size fractions represent fragmental skeletal remains of invertebrates, particularly, crinozoans, bryozoans and articulate brachiopods. This “Carbonate Factory” occupied most of the North American midcontinent that was covered by warm, shallow seawater. The Burlington Shelf (Lane 1978), which occupied what is mostly the State of Missouri now, produced the carbonate mud and grains that were transported down-ramp in northern Arkansas. Other similar depositional settings developed across the midcontinent during its greatest covering by shallow, continental seas between the Lower Ordovician and the Cretaceous.

Sunlight most certainly lighted the seafloor promoting the growth of the green algae and the life cycles of microscopic plants and animals that would serve as the food source for the invertebrates that were all filter-feeders. Life and death processes occurred within effective wave-base, which disarticulated both algae and invertebrates, and provided the energy to move this sediment toward the craton margin and down the adjacent ramp in a lobate manner.

Although these Lower Mississippian limestones are bioclastic, the faunal diversity is actually quite limited. Crinozoan detritus comprises nearly all of the bioclasts in most intervals. The abundance of crinoids and absence of other invertebrates reflects the high rate of deposition and instability on the Burlington Shelf. Most Paleozoic invertebrates prefer a low rate of sedimentation and stable substratum, because a constantly moving substratum would bury both sessile and infaunal organisms (Purdy 1963a,b, Ball 1967). If modern analogues can be applied, green algae living on the Burlington Shelf wouldn't be affected by burial because their life spans are too short. They lack roots, but the external thallus can form a holdfast, and they can withstand modest storms. For the crinoids, their long stalks provided protection from burial and allowed them to exploit a food supply higher in the water column. In contrast, smaller sessile invertebrates, such as brachiopods, could easily be covered by modest sedimentation rates and periodic storm activity. Consequently, crinoids and organisms with mutual, commensal, or symbiotic relationships with them would likely be the only invertebrates preserved in the Lower Mississippian sediments.

Conclusions

The Lower Mississippian succession represents an unconformity-bounded, third-order, transgressive-regressive cycle deposited on the southern edge of a broad carbonate platform known as the Burlington Shelf much of which is now physiographically, the Ozark Dome. The St. Joe-Boone interval nomenclature lacks uniformity, but the “stateline fault” with Missouri for the St. Joe interval has been eliminated by recognizing the Missouri formations in Arkansas as members (ascending order): Bachelor, Compton, Northview, Pierson of the St. Joe Formation. The Boone interval in Missouri is represented by the (ascending order): Reeds Spring, Elsey, Burlington-Keokuk undifferentiated, but those names have not been applied with confidence in Arkansas. Instead, Boone is retained as the oldest valid name applied to the interval in Arkansas, divided into informal lower and upper members based on chert development: dark, nodular, penecontemporaneous chert in the lower Boone, and white to gray, later diagenetic replacement chert in the upper Boone.

The Burlington Shelf “carbonate factory” created the carbonate sediments that are seen within the St. Joe-Boone succession in northern Arkansas. The carbonate sediments were produced predominantly by two processes, lime mud from green algae and sand fraction mostly from crinozoan detritus. These sediments were moved from their origin on the Burlington Shelf in present-day Missouri, and transported down ramp in a lobate manner to their site of deposition in present-day northern Arkansas.

Acknowledgements

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Evaluation of Education and Other Influential Factors on the Perceptions of Influenza Vaccinations

S.D. Mills, S.R. Charlton* and B.M. Rowley**

Department of Psychology and Counseling, University of Central Arkansas, Conway AR 72035
Department of Biology, University of Central Arkansas, Conway, AR 72035

*Correspondence: scharlton@uca.edu
**Correspondence: browley@uca.edu

Running Title: Education and Other Influential Factors on the Perceptions of Influenza Vaccinations

Abstract

Influenza is a potentially deadly contagious viral infection that attacks the respiratory system. The 1918 influenza pandemic infected approximately 1/3 of the world's population and resulted in an estimated 50 million deaths globally. Research has led to the production of influenza vaccinations. Unfortunately, there continues to be influenza epidemics that are responsible for killing numerous people annually. One reason for the continued death toll from influenza is the lack of people receiving a yearly flu vaccination. In order to gain more public acceptance for influenza vaccinations, it is important to understand the factors influencing the choice to be vaccinated. A study was conducted on 191 undergraduate general psychology students at the University of Central Arkansas to test if specific factors determine the predictability of vaccination acceptance. Education and positive influential factors toward flu vaccinations are two important factors presented in the study that have influence on participants receiving the vaccine. The study results are beneficial in understanding why people reject flu vaccines and what can be done to reverse those decisions.

Introduction

Influenza is a communicable disease that causes high morbidity and relatively high mortality rates that occur at both local and global levels (Frew et al. 2013, Lawrence 2014, Seike et al. 2016). The disease severity can range with symptoms including fever, coughing, sore throat, runny or stuffy nose, headaches, muscle or body aches, fever, and fatigue (CDC 2016b). In the United States, many different variables can determine the severity of these symptoms and can lead to other diseases or complications (CDC 2016a). These variables include the strain of the virus that is circulating, the timing of the season, how well the vaccine is working, and how many people get vaccinated (CDC 2016a, and 2016b). Although studies have shown that seasonal influenza immunizations decrease these rates, there are still large numbers of people not receiving yearly vaccinations (Frew et al. 2013).

In the 2014-15 influenza season, it was predicted that influenza vaccinations prevented around 67,000 influenza-associated hospitalizations (Cohen et al. 2015). 1.9 million illnesses and 966,000 medical visits were also estimated as being prevented by influenza vaccinations (Cohen et al. 2015). Influenza vaccinations were estimated, over 6 influenza seasons, (2005-2011) to have averted 13.6 million illnesses, 5.8 million medical visits, and 112,900 influenza-related hospitalizations (Kostova et al. 2013).

Despite several studies resulting in high influenza vaccine effectiveness, many people are still not receiving yearly vaccinations. According to many studies, the young adult population, ages 18-49, has the lowest influenza vaccination rates compared to other groups (Lawrence 2014, Ravert et al. 2012, Poehling and Katherine 2012, Ramsey and Merczinski 2011, Nichol et al. 2005, Cohen et al. 2015). Colleges, which typically encompass adults in this age group, are a concern. A survey in fall 2009 found that only 15.8% of US university students intended to get vaccinated against influenza. Similar surveys carried out on college students in Italy, Israel, and Turkey indicated less than 25%, 13.9%, and 7.2% (respectively) reported intentions of getting vaccinated against influenza infection (Ravert et al. 2012). Since college students are exposed to different social settings, they have increased chances of becoming infected with and spreading diseases such as influenza. Having the lowest acceptance of influenza vaccination, increase in illnesses, hospitalization and deaths from the disease become more likely as well (Ravert et al. 2012, Van et al. 2010). The lack in vaccination acceptance is a significant problem leading to elevated death rates caused from influenza each year. Therefore, it is very important to understand the factors influencing the choice to be vaccinated in order to gain more public acceptance for the vaccine.

A study done at Northern Kentucky University found that 50% of participants believed themselves to be healthy individuals (Ramsey and Merczinski 2011). These students consequently believed they would not be at risk for becoming seriously ill if they were to contract the H1N1 influenza virus. This led the students to not get vaccinated as they thought it to be unnecessary. Other studies similar to this one focus on perceived susceptibility and prior seasonal influenza vaccination as two main factors determining influenza vaccination acceptance (Ramsey and Merczinski 2011, Gidengil et al. 2012, Xu and Peng 2015).

A study performed at a large Midwestern university reported that vaccine efficacy and safety concerns were predictors for college students' intentions to accept H1N1 influenza vaccinations (Ravert et al. 2012). A similar study in the United Kingdom found that seasonal changes in influenza vaccine composition cause uncertainty and distrust (Gidengil et al. 2012). This resulted in low influenza vaccination uptake by the participants in the study.

Misconceptions and lack of education both tend to be more of a determining factor over other variables (Ward and Raude 2014). Many people without a biology or immunology background have trouble understanding why influenza vaccinations are beneficial and why they are necessary to repeat yearly. This leaves many people vulnerable to accepting unreliable information which may keep them from receiving the annual influenza vaccination.

The objective of this study was to examine factors that may influence students' perception on receiving influenza vaccinations. Several studies have attempted to analyze the arguments that adults use when describing their perspective on the need for influenza vaccinations. The Prospect Theory and Health Belief Model have both been used, but have been unable to yield consistent results across different studies (Frew et al. 2013, Ravert et al. 2012). Other studies focus on one to two factors. Varied results from study to study could be due to the different views coming from different geographical locations (Prati et el. 2011). It is important to understand characteristics of seasonal influenza epidemic patterns, as well as acceptance of vaccination against influenza in different areas, in order to implement better educational and preventative measures (Seike et al. 2016). This study, unlike others to date, focuses on understanding these characteristics in students specifically at the University of Central Arkansas.

Methods and Materials

One hundred ninety-one undergraduate psychology students (154 females; 36 males; mean age = 20.56, SD = 3.39) participated in these experiments for extra course credit. There was no significant difference in ages between genders ($t(186) = 0.47$, $p = 0.64$). One participant failed to offer gender data.

The study was completed through Qualtrics.com. Participants first had to agree to participate by a digital informed consent letter, after which they completed an online survey. The survey began with demographic questions asking for the participant's age and gender. Next, participants answered questions regarding their history including their past associations with influenza vaccinations. This section included questions asking if they had ever had an influenza vaccination. If they had, they were next asked if they had received an influenza vaccination in the last year and if they receive them yearly. Then, the students were asked whether or not they had been vaccinated the year of the study. If they had not been vaccinated, they were asked if they planned to get the influenza vaccine.

Next, students were given a pre-test including 5 multiple choice questions to assess their knowledge on background influenza information. "What is the flu?", "During the 1918 pandemic, about how many people died globally from the flu?", and "How does the flu spread?" are examples of the questions in this section.

The participants were then given 16 statements and asked to rate them on how/if the statements influenced their decisions on getting the influenza vaccination in the past. They rated them by selecting one out of five options. They rated them as strongly or somewhat influential to not get the vaccination, neutral, or as strongly or somewhat influential to not get the vaccination. Examples of the statements include: "being a normal healthy adult", "parents or guardians", and "pain of the shot".

Next, the students went through a tutorial that consisted of 15 slides that instructed them on the basics of the influenza vaccination. Slides 1-3 explained what the flu is and that getting the flu shot each year is the best way to prevent the flu from spreading and attacking. Slides 4-6 reviewed the signs, symptoms, epidemics, and pandemics that have been or are caused by the flu. Slides 7-8 discuss how the flu spreads, higher risk groups, and who is able to receive the flu vaccination. Slides 10 and 11 described the importance of the yearly flu shot through an immunologic view point. Slides 12-15 explained other prevention/treatment methods, the cost for a flu shot for students at the University of Central Arkansas, and further resources for more information.

Then the participants were asked the same 5 multiple choice questions as in the pre-test about the background flu information. Students were also again asked if they planned to get a flu vaccination this year. Finally, the students were sent to a screen with a debriefing letter.

All analyses were conducted in SPSS 22.0. A t-test was used to compare the age differences in males and females. In pre and post-test comparison, 2 questions were eliminated because they were answered correctly by 95% of participants on both the pre and the post test. T-tests with Bonferroni adjusted p-values to correct for multiple comparisons (critical p = 0.05/4 = 0.0125) were used to look at pre/post differences for questions 1, 2, 3, and the total score. An ANOVA was used to compare differences in the vaccine influence scale based on reported plans to get the vaccine before and after the tutorial (yes/yes, no/no, and yes/no). Post hoc testing used Tukey's multiple comparisons.

Results

Table 1 represents the counts of students' yes or no answers to plans to get their flu vaccination this year before and after the educational tutorial. Participants were asked if they planned to get their influenza vaccination the year of the study once before and after the tutorial. 81 participants chose yes before taking the tutorial and then yes after. 21 participants chose no before taking the tutorial, then yes after (12.5%). 66 participants chose no before taking the tutorial, then no after. The last 23 participants who already had their vaccination the year of the study did not answer this question.

Table 1: Counts of students yes and no answers to receiving the flu vaccination before and after the educational tutorial.

		After Tutorial		Total
		Yes	No	
Before Tutorial	Yes	81	0	81
	No	21	66	87
	Total	102	66	168

Figure 1 represents the mean pre and post-test student scores on 5 multiple-choice questions. The data was separated by students' yes or no answers on whether to be vaccinated this year based before and after the exposure to the educational tutorial. Out of the 5 multiple-choice questions, 2 had a low variation from the pre-test to the post-test, having more than 95% of the participants who answered correctly in both sections. Therefore, only the other 3 multiple choice questions were considered to assess what was learned by participants from the tutorial.

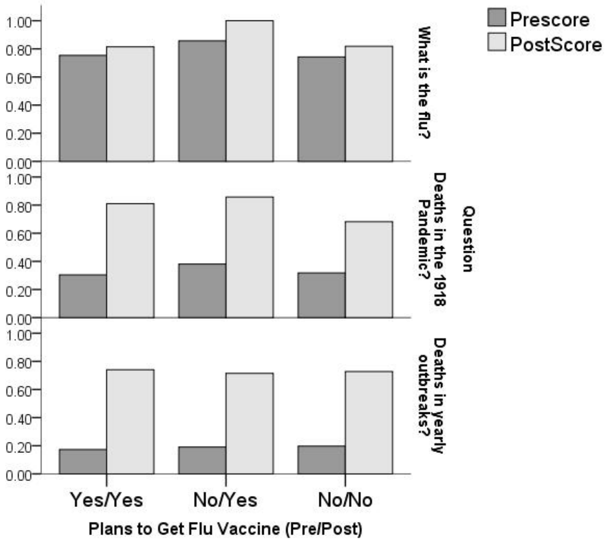

Figure 1: Post-test scores were significantly higher than the pre-test scores in each group based on students' plans to get the flu vaccination this year (t(187) = -13.937, p < 0.001).

The multiple choice questions were analyzed by marking the 3 answers that were incorrect as 0 and the one answer that was correct as 1. For the first multiple choice question, 77% of the participants answered correctly for the pre-test, and 84.3% of participants answered correctly for the post-test. For the second multiple choice question, 31.4% of the participants answered correctly for the pre-test, and 77% of participants answered correctly for the post-test. For the third multiple choice question, 19.9% of the participants answered correctly for the pre-test, and 74.3% of participants answered correctly for the post-test.

The total questions answered correctly from the pre-test, then the post-test, were calculated by using the sum score for questions 1, 2, and 3 with a range of 0-3 questions. The mean pre-test total score was calculated (m =1.30 questions answered correctly, SD = 0.68).

Then the mean post-test score was calculated (m = 2.37 questions answered correctly, SD =0.87. Overall, the mean post-test score was significantly higher than the pretest (t(187) = -13.937, p < 0.001).

Figure 2 represents average scores students received from ranking statements on influence factors. Participants selected one of five different options for each of the 16 statements regarding possible influential factors. The statements chosen as neutral were considered as 3; therefore, a score of 3 was standardized to be 0. The statements chosen as strongly influencing against influenza vaccination were given a score of -2. The statements chosen as somewhat influencing against getting influenza vaccinations were given a score of -1. The statements chosen as neutral were given a score of 0. The statements chosen as somewhat influencing for getting influenza vaccinations were given a score of 1. The statements chosen as strongly influencing for getting influenza vaccinations were given a score of 2. Overall, the mean influence score was 0.14, meaning that most of the statements were influential towards receiving the influenza vaccination. Participants that chose yes on planning to get the influenza vaccination both before and after the tutorial had a mean influential score of 0.34, SD = 0.62. These participants were overall influenced positively by the different factors towards getting the vaccination. Participants that chose no on planning to get their vaccination before the tutorial then yes after the tutorial had a mean influential score of 0.20, SD = 0.54. These participants were also overall influenced positively by the different factors towards getting the vaccination. Participants that chose no on planning to get their vaccination both before and after the tutorial had a mean influential score of -0.17, SD = 0.38. These participants were overall influenced negatively by the different factors against getting the vaccination.

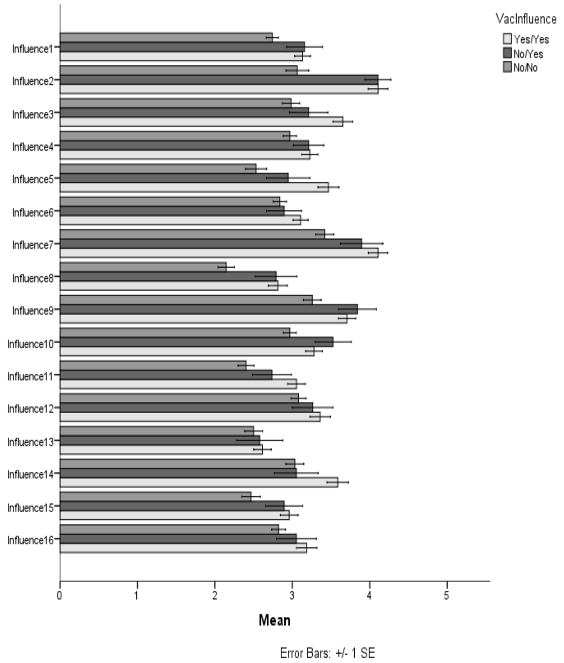

Figure 2: Average influence score based on students' plans to get the flu vaccination this year.

Discussion

One of the main probable factors that influence people on whether or not to obtain a seasonal influenza vaccine is education. This was tested in the study by giving participants a pre-test before a basic influenza vaccination tutorial and then giving them the same test after the tutorial. Next, students were asked both before and after the tutorial if they planned to get their vaccination the year of the study. The results indicated a significant correlation between education and influenza vaccinations. Overall, the students scored higher in the post-test compared to the pre-test. This suggests that they learned basic influenza vaccination information from the tutorial that they previously did not know. The results also indicated that a significantly higher amount of students planned to get their vaccination after gaining basic influenza vaccination information from the tutorial.

Other probable factors were also tested to determine predictability of vaccination acceptance. For the participants that planned to get the influenza vaccination both before and after the tutorial, the factors seemed to have had an overall positive influence towards them getting the vaccination. For the participants who at first did not plan to get the vaccination, but planned to get the vaccination after the tutorial, the factors seemed to also have had an overall positive influence towards them getting the vaccination. For the participants who planned to not get the vaccination both before and after the tutorial, the factors seemed to have an overall negative impact against them getting the vaccination. Therefore, participants who were already positively influenced by the different factors to get vaccinated were more likely to plan to get vaccinated after being educated from the tutorial. The participants who were already negatively influenced by the different factors to not get vaccinated were less likely to plan to get vaccinated after being educated from the tutorial.

Globally, there is a public health challenge of gaining effective communication and engaging with members of the general public in order to increase vaccination rates (Liao et al. 2014, Davis et al. 2015). Unfortunately, many factors have been linked to an abundance of individuals resisting to get the flu shot (Frew et al. 2013, Ravert et al. 2012, Gidengil et al. 2012, Ward and Raude 2014). Basic influenza education and positive influential factors toward getting influenza vaccinations are two important factors presented in the study that have great influence on whether participants decide to receive the vaccine. The study results here and in the related studies are beneficial as they can be used to help understand ways of increasing influenza vaccine acceptance rates. Increased influenza vaccine acceptance will result in a decrease in the number of deaths that result yearly from influenza and relieve the amount of health services that is being taken up in response to the disease (Tjon-Kon-Fat et al 2016).

One method that this study points to as being effective could be to first educate more people on the basics of influenza vaccinations. In order to educate, the information needs to be approachable by the general public and not just to those with science, biology, or immunology backgrounds. Another method would be to utilize influential factors that are positive toward receiving the vaccine. Education had less of an effect when students already had negative perceptions from influential factors about the vaccine. Putting more positive influential factors in the public's eye could have a large impact by increasing influenza vaccination acceptance rates.

Studies performed to date on this topic have conflicting results showing varying factors as being more significant in one area over the next. This means that it could be important to gain knowledge through local studies to determine the best way to reach out to people in that specific area. Although this study had a low amount of participants compared to others, no other influenza vaccination acceptance study has been done in Arkansas. This study will add to the others like it from different geographic areas to further show the similarities and differences in studies performed locally versus globally. This study also is focused on college students which have been determined to have the lowest flu shot acceptance rate (Lawrence 2014, Ravert et al. 2012, Poehling and Katherine 2012, Ramsey and Merczinski 2011, Nichol et al. 2005, Cohen et al. 2015). This is an important aspect to consider as an increase in college student influenza vaccination reception can have a more positive impact on increasing herd immunity and decreasing influenza illnesses, hospitalizations, and death rates.

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Electron Shock Waves with a Large Current behind the Shock Front

H.D. Newberry, M. Hemmati*, H.D. Moore, K. Ledbetter, and M.W. Bowman

Arkansas Tech University, Department of Physical Science, Russellville, AR 72801, USA

Correspondence: mhemmati@atu.edu

Running Title: Electron Shock Waves with a Large Current behind the Shock Front

Abstract

The propagation of breakdown waves in a gas, which is primarily driven by electron gas pressure, is described by a one-dimensional, steady-state, three-component (electrons, ions, and neutral particles) fluid model. We consider the electron gas partial pressure to be much larger than that of the other species and the waves to have a shock front. Our set of equations consists of the equations of conservation of the flux of mass, momentum, and energy coupled with Poisson's equation. This set of equations is referred to as the electron fluid dynamical equations. In this study we are considering breakdown waves propagating in the opposite direction of the electric field force on electrons (return stroke in lightning) and moving into a neutral medium.

For Breakdown waves with a significant current behind the shock front, the set of electron fluid dynamical equations and also the boundary condition on electron temperature need to be modified. For a range of experimentally observed current values and also some larger current values which few experimentalists have been able to observe, we have been able to solve the set of electron fluid dynamical equations through the dynamical transition region of the wave. Some experimentalists have reported the existence of a relationship between return stroke lightning wave speed and current behind the shock front; however, some others are skeptical of the existence of such a relationship. Our solutions to the set of electron fluid dynamical equations within the dynamical transition region of the wave confirm the existence of such a relationship. We will present the method of solution of the set of electron fluid dynamical equations through the dynamical transition region of the wave and also the wave profile for electric field, electron velocity, electron temperature and electron number density, within the dynamical transition region of the wave.

Introduction

Electron shock waves, also known as breakdown waves, were first observed in the form of lightning and studied in laboratory discharge tubes. The phenomenon occurs when the potential difference between two points is high enough to ionize some of the neutral particles and later accelerate the resulting electrons to generate an avalanche-like shock wave. This process converts an ion-less gas into a neutral plasma and results in a high temperature electron gas that expands rapidly to produce an electron shock wave. The emitted radiation has been found to have no Doppler shift; therefore, the ions have no significant mass motion through the wave. When the net electric field force on electrons, applied plus space charge field force, acts in the same direction as the propagation of the wave, the wave is referred to as a pro-force wave. Waves for which the electric field force on electrons is in the opposite direction as the wave propagation are labeled, by definition, as anti-force waves. In the case of anti-force waves, the electron gas temperature, and therefore electron gas partial pressure, is large enough to provide the driving force for the propagation of the wave.

The breakdown wave can be broken into two distinct regions: the Debye sheath region and the quasi-neutral region. The Debye sheath region is a thin, dynamical region that follows the shock front. In the sheath region, the net electric field starts at its maximum value at the shock front and reduces to a negligible value at the trailing end of the sheath. Also electrons, starting from an initial speed behind the shock front, slow down to a speed comparable to that of heavy particles. Following the sheath region of the wave, exists a much longer region referred to as the quasi-neutral region of the wave. In the quasi-neutral region, the electron gas cools down through further ionization of the neutral particles, and ion and electron densities become approximately equal.

Model

Paxton and Fowler (1962) were first to formulate a fluid model for breakdown waves which led to a one-dimensional, three component, steady state theory that described breakdown waves propagating into a non-ionized media and in the direction of the electric field force on electrons. The set of equations included conservation of mass, momentum, and energy, and their solutions for the set of equations presented some success. Prior to 1984, Fowler and his associates (1968) added Poisson's equation to the set of fluid equations developed by Paxton (1962), and were able to solve their set of equations using an approximation method. The approximate solutions for the more developed set of equations showed better agreement with experimental results than those presented by Paxton (1962). In the approximate solutions to the set of equations, to make solutions possible, many terms were neglected from the equation of conservation of energy. Fowler et al. (1984) added the previously neglected terms into the equation of conservation of energy, particularly the heat conduction term, which altered the boundary condition on electron velocity and proved to be essential in an exact numerical solution of the set of electron fluid dynamical equations within the dynamical transitional region of the wave. Fowler et al. (1984) complete set of equations for breakdown waves propagating into a non-ionized medium and in the direction of the electric field force on electrons is as follows

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

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

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

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

In the above equations, E is the electric field magnitude in the sheath region, M is the neutral particle mass, K is the elastic collision frequency, V is the wave velocity, x is the position within the sheath region, E_o is electric field at the wave front, ϕ is the ionization potential, and β is the ionization frequency. Also, e, v, m, n, and T_e, are electron charge, velocity, mass, number density, and temperature, respectively. To allow for easier solution of these equations, Fowler et al. (1984) introduced the following set of dimensionless variables for proforce breakdown waves:

$\eta = \frac{E}{E_0}$ $\quad\omega = \frac{2m}{M}$ $\quad\mu = \frac{\beta}{K}$

$\xi = \frac{xeE_o}{mV^2}$ $\quad\psi = \frac{v}{V}$ $\quad\theta = \frac{T_e k}{2e\phi}$

$\nu = \frac{n2e\phi}{\varepsilon_o E_o^2}$ $\quad\alpha = \frac{2e\phi}{mV^2}$ $\quad\kappa = \frac{mV}{eE_o}K$

Where, η, μ and ξ are dimensionless electric field, ionization rate, and position within the sheath region of the wave, respectively. Also, ν, ψ, and θ, are the dimensionless electron number density, velocity, and temperature. α and Κ are wave parameters. Substituting these dimensionless variables into equations 1-4 yields a set of electron fluid dynamical equations in nondimensional form for proforce waves propagating into a non-ionized media. They are as follows:

$$\frac{d}{d\xi}[\upsilon\psi] = \kappa\mu\nu \tag{5}$$

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

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

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

To transform these equations into a set describing antiforce breakdown waves, some modifications are needed. Previously Sanmann and Fowler (1975) approximated solutions for antiforce waves by considering a weak discontinuity at the wave front and used a simple sign change for Κ and μ. Considering waves to have a shock front, however, Hemmati (1999) showed Sanmann's (1975) simple change of variable signs were not accurate. Hemmati (1999) derived a new set of non-dimensional variables for the antiforce case and they are

$$\eta = \frac{E}{E_0}, \qquad \omega = \frac{2m}{M}, \qquad \mu = \frac{\beta}{\mathrm{K}},$$

$$\xi = -\frac{xeE_o}{mV^2}, \qquad \psi = \frac{v}{V}, \qquad \theta = -\frac{T_e k}{2e\phi},$$

$$\nu = \frac{n2e\phi}{\varepsilon_o E_o^2}, \qquad \alpha = \frac{2e\phi}{mV^2}, \qquad \kappa = \frac{mV}{eE_o}K$$

After applying these new non dimensional variables, Hemmati's (1999) new set of non-dimensional, electron fluid dynamical equations for antiforce waves become

$$\frac{d}{d\xi}[\upsilon\psi] = \kappa\mu\nu \tag{9}$$

$$\frac{d}{d\xi}[\nu\psi(\psi-1)+\alpha\nu\theta] = \nu\eta - \kappa\nu(\psi-1) \tag{10}$$

$$\frac{d}{d\xi}\left(\nu\psi(\psi-1)^2+\alpha\nu\theta(5\psi-2)+\alpha\nu\psi - \frac{5\alpha^2\nu\theta}{\kappa}\frac{d\theta}{d\xi}\right) = 2\nu\eta(\psi-1) - \omega\kappa\nu[3\alpha\theta+(\psi-1)^2] \tag{11}$$

$$\frac{d\eta}{d\xi} = -\frac{\nu}{\alpha}(\psi-1) \tag{12}$$

Hemmati et al. (2011) modified the set of electron fluid dynamical equations to describe antiforce waves (return stroke in lightning) with a significant current behind the shock front. With ion number density, Ni, and ion velocity, Vi, behind the wave front, the current behind the wave front will be

$$I_1 = eN_iV_i - env \tag{13}$$

Ion velocity is considered to be almost equal to neutral particle speed ($V_i \cong V$) due to lack of experimentally observed Doppler shift. No experimentally observed Doppler shift indicates that both the ions and neutral particles have insignificant speeds in the laboratory frame. Substituting V for V_i and solving for N_i from equation 13 yields

$$N_i = \frac{\mathrm{I}_1}{eV} + \frac{nv}{V} \tag{14}$$

Substituting this into Poisson's equation, and applying the dimensionless variables for antiforce waves results in

$$\frac{d\eta}{d\xi} = \frac{\mathrm{KI}_1}{\varepsilon_0\mathrm{KE}_0} - \frac{v}{\alpha}(\Psi-1) \tag{15}$$

Poisson's equation is then reduced to

$$\frac{d\eta}{d\xi} = \mathrm{K}\iota - \frac{v}{\alpha}(\Psi-1) \tag{16}$$

Where $\iota = \frac{\mathrm{I}_1}{\varepsilon_0\mathrm{KE}_0}$ represents the dimensionless current. The current values behind the shock front in lightning return stroke are generally in the range of 5 to 30 kA. Using a current value of I_1= 10kA for lighting return stroke, the elastic collision frequency, K, values from (McDaniel, 1964), and also the values of ε_0, and E_0, one can estimate the value of ι to be of the order of 1.

Solving for v(Ψ-1) from equation (16) and substituting it into the equation of conservation of energy for antiforce waves, equation (11), produces the final form of the equation of conservation of energy for antiforce waves with a large current behind the wave front. This completes the final form of the set of electron fluid dynamical equations describing antiforce waves with a large current behind the shock front

$$\frac{d}{d\xi}[\upsilon\psi] = \kappa\mu\nu \tag{17}$$

$$\frac{d}{d\xi}[\nu\psi(\psi-1)+\alpha\nu\theta] = \nu\eta - \kappa\nu(\psi-1) \tag{18}$$

$$\frac{d}{d\xi}\left(\nu\psi(\psi-1)^2+\alpha\nu\theta(5\psi-2)+\alpha\nu\psi - \frac{5\alpha^2\nu\theta}{\kappa}\frac{d\theta}{d\xi} + \alpha\eta^2\right) = 2\eta\kappa\iota\alpha - \omega\kappa\nu[3\alpha\theta+(\psi-1)^2] \tag{19}$$

$$\frac{d\eta}{d\xi} = \kappa\iota - \frac{\nu}{\alpha}(\psi-1) \tag{20}$$

To solve the set of electron fluid dynamical equations for antiforce waves with a large current behind the shock front, Hemmati et al. (2015) had to modify the initial condition on electron temperature as well. They used the all particle (global) momentum equation to find the shock condition on electron temperature, and in dimensionless form, the electron temperature at the shock front becomes

$$\theta_1 = \frac{\Psi_{1(1-\Psi_1)}}{\alpha} - \frac{\mathrm{K}\iota}{\nu_1}. \tag{21}$$

Results and Discussion

A trial and error technique of integration was used to obtain solutions for our complete set of electron fluid dynamical equations through the dynamical transition (sheath) region of the wave. For a specific wave speed, α, and dimensionless current, ι, a set of values for wave constant, Қ, electron number density, ν_1 , and electron velocity, Ψ_1, at the wave front were chosen, and in integration of the set of equations through the sheath region of the wave, those values were systematically changed until the integration of the set of electron fluid dynamical equations through the sheath region of the wave resulted in a successful conclusion. Meaning that, at the conclusion of the integration of the set of equations, $\Psi_2 \rightarrow 1$, and, $\eta_2 \rightarrow 0$, at the trailing edge of the wave. Integration of our set of electron fluid dynamical equations for higher wave speed values, meaning for small α values, is not very challenging; therefore, we intended to find solutions for lower ranges of wave speed values. For a certain wave speed value, α, integration of the set of electron fluid dynamical equations through the sheath region of the wave for small dimensionless current values, ι, also is relatively straight forward; however, as the dimensionless current value increases, the sheath thickness increases as well and the integration of the set of equations through the sheath region becomes more involved and time consuming. For a specific wave speed value, we intended to find the largest current value for which integration of the set of electron fluid dynamical equations through the sheath region of the wave became possible. For four wave speed values shown below and for the largest dimensionless current values for which integration of the set of electron fluid dynamical equations through the sheath region of the wave, for respective wave speeds became possible, the following set of initial boundary values and wave constants had to be employed.

α = 1 ι = 0.5 Қ= 0.1338 ν_1 = 0.4882 Ψ_1=0.5502

α = 0.25 ι = 1 Қ= 0.33 ν_1 = 0.81 Ψ_1=0.85

α = 0.05 ι = 2 Қ= 0.6 ν_1 = 0.7655 Ψ_1=0.8876

α = 0.005 ι = 5 Қ= 1.34 ν_1 = 0.525 Ψ_1=0.5469

The following figures represent the wave profile for antiforce waves with a significant current behind the shock front. Figures 1 through 3 show that solutions to the set of electron fluid dynamical equations within the sheath region of the wave all have met the required boundary conditions at the trailing edge of the wave ($\Psi_2 \rightarrow 1,\ \eta_2 \rightarrow 0$).

Figure 1 shows dimensionless electric field, η, as a function of dimensionless electron velocity, ψ, within the sheath region of the wave for four values of wave speed, α, and respective dimensionless current values, ι.

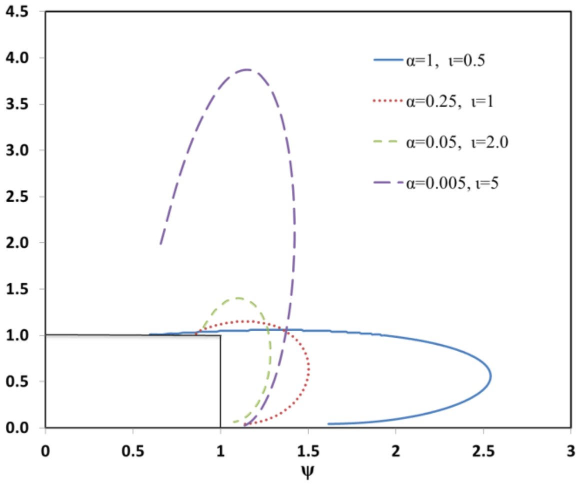

Figure 1. Electric field, η, as a function of electron velocity, ψ, for four dimensionless wave speed values, α, and respective dimensionless current values, ι, of 1, 0.5; 0.25, 1.0; 0.05, 2.0 and 0.005, 5.0 within the sheath region of the wave.

Figure 2 shows dimensionless electric field, η, as a function of dimensionless position, ξ, within the sheath region of the wave for four wave speed values, α, and respective dimensionless current values, ι.

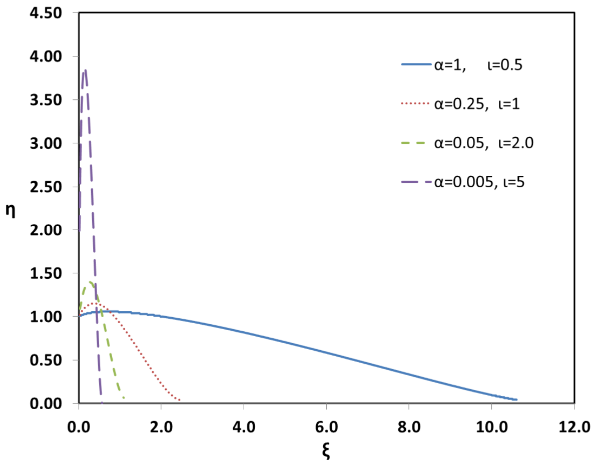

Figure 2. Dimensionless electric field, η, as a function of dimensionless position, ξ, for four wave speed values, α, and respective dimensionless current values, ι, of 1, 0.5; 0.25, 1.0; 0.05, 2.0 and 0.005, 5.0 within the sheath region of the wave.

Figure 3 shows dimensionless electron velocity, ψ, as a function of dimensionless position within the sheath region of the wave for four wave speed values, α, and respective dimensionless current values, ι.

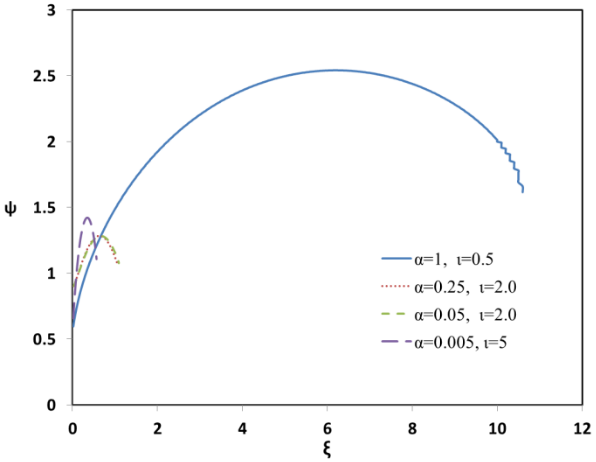

Figure 3. Dimensionless electron velocity, ψ, as a function of dimensionless position, ξ, for four wave speed values, α, and respective dimensionless current values, ι, of 1, 0.5; 0.25, 1.0; 0.05, 2.0 and 0.005, 5.0 within the sheath region of the wave.

Figure 4 shows dimensionless electron number density, υ, as a function of dimensionless position, ξ, within the sheath region of the wave for four wave speed values, α, and respective dimensionless current values, ι.

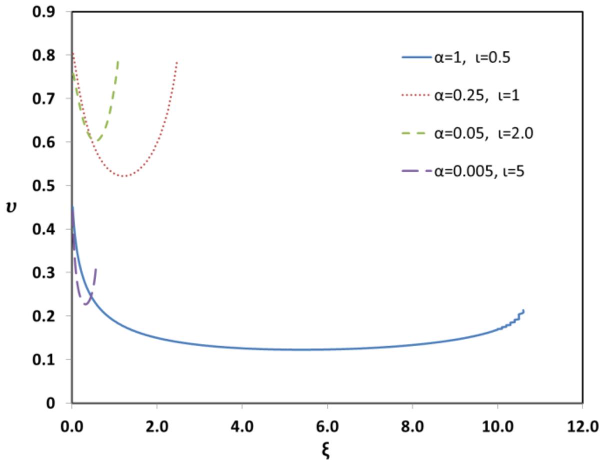

Figure 4. Dimensionless electron number density, υ, as a function of dimensionless position, ξ, for four dimensionless wave speed values, α, and respective dimensionless current values, ι, of 1, 0.5; 0.25, 1.0; 0.05, 2.0 and 0.005, 5.0 within the sheath region of the wave.

Figure 5 shows dimensionless electron temperature, θ, as a function of dimensionless position, ξ, within the sheath region of the wave for four wave speed values, α, and respective dimensionless values, ι, graphed with a logarithmic scale on the y axis. α =0.005 represents a relatively fast wave speed value of 4.2×10^7 m/s, and α = 1 represents slow wave speed value of 3×10^6 m/s. Short dimensionless sheath thickness, ξ, value of, 0.56 represents an actual sheath thickness of 5.6 mm

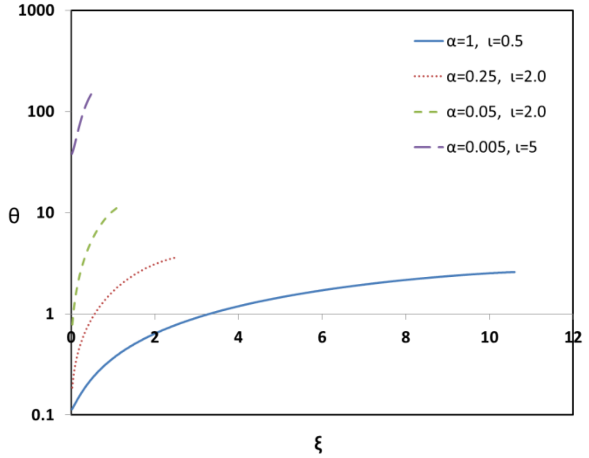

Figure 5. Dimensionless electron temperature, θ, as a function of dimensionless position, ξ, for four wave speed values, α, and respective dimensionless current values, ι, of 1, 0.5; 0.25, 1.0; 0.05, 2.0 and 0.005, 5.0 within the sheath region of the wave.

Researchers have debated the possible existence of a relationship between wave speed values and peak current values in lightning return strokes. For instance, Wagner (1963) has suggested that as the lightning return stroke wave speed increases, it can support larger peak current values; but others, notably Mach and Rust (1989) disagree, claiming a lack of correlation between return stroke propagation speed and peak current. Our solutions indicate that a relationship does exist, as the lightning return stroke speed increases, it can support higher peak current values.

Investigators, for example, Rakov (2007), have reported minimum wave speeds for lightning return stroke typically to be in the order of 10^7m/s. However, as we indicated above, we have been able to integrate our set of electron fluid dynamical equations through the sheath region of the wave for lightning return stroke speeds as low as 3×10^6 m/s. Thus, our model predicts that antiforce waves with wave speeds below that of those experimentally measured can be detected.

Conclusions

Our modified set of electron fluid dynamical equations for antiforce waves with a large current behind the wave front, with modified electron temperature at the shock front, have been utilized in our integration of the set of electron fluid dynamical equations through the sheath region of the wave. Our solutions for several wave speed values, with maximum currents possible for the selected wave speeds, all meet the expected physical conditions at the trailing edge of the dynamical transition region of the wave. This indicates validity of our modified set of electron fluid dynamical equations and the extent and possible range of wave speed values and currents for lightning return strokes. Our solutions indicate that lightning return stroke speeds lower than the ranges reported by the majority of experimentalists are also possible. Our solutions also indicate, for lightning return stroke, as the wave speed increases, it can support larger currents behind the shock front. This means that in a lightning return stroke, a relationship between the wave speed values and peak currents exists.

Acknowledgements

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Sedimentation in the Upper Reaches of Lake Ouachita

J.A. Patton

Department of Physical Sciences, Arkansas Tech University, Russellville, AR 72801

Correspondence: jpatton@atu.edu

Running Title: Sedimentation in the Upper Reaches of Lake Ouachita

Abstract

Lake Ouachita in west-central Arkansas is the largest man-made reservoir in the state. The lake was created by the U.S. Army Corps of Engineers (USACE) in 1953 for the purposes of hydropower, flood control, and recreation. Although Lake Ouachita is widely known for its high water clarity near Blakely Dam, little is known about the volume and ultimate fate of sediments that enter the lake from two primary tributaries: the North and South Forks of the Ouachita River. This project utilized a dual-frequency echo sounding system in combination with geographic information system and statistical analysis to calculate an average post-impoundment sediment thickness of approximately 0.78 m present throughout the study area, with a maximum sediment thickness of 2.93 meters. The total volume of post-impoundment sediment in place was calculated as 2,750,000 m^3 and the average linear sediment accumulation rate was determined to be 1.3 cm y^{-1}. Variations within the project area show widespread sediment focusing with statistically significant variations in sediment thickness between littoral and deeper zones, as well as between the lotic-transitional and lacustrine zones.

Introduction

Lake Ouachita was created as an impoundment on the Ouachita River in 1953 for the purposes of hydropower, flood control, and recreation. At over 16,000 hectares, it is the largest lake completely contained within the state. Known throughout the south as a popular scuba diving destination because of the high water clarity (low total suspended solids) near Blakely Dam, little is known about sediments entering the lake through the two primary tributaries: the North and South Forks of the Ouachita River. Located more than 40 kilometers from the dam, these tributaries potentially transport significant quantities of sediment that is deposited in the western reaches of the lake.

Reservoir sedimentation is commonly investigated using hydroacoustic mapping of post-impoundment sediment to calculate total sediment volumes (Dunbar et al. 1999, Odhiambo and Boss 2004, USBR 2006, Elci et al. 2009, Anderson et al. 2013). The process uses a dual-frequency echo sounding (DFES) system to simultaneously measure both modern-day bathymetry and the pre-impoundment surface. The 200 kHz pulse bounces off the modern-day bottom, providing real-time bathymetric depths, while the 20 kHz pulse penetrates the fine-grained, low density lacustrine sediments and bounces off the high-density pre-impoundment surface. Depth differences between the two signals indicate the total amount of sediment accumulated since impoundment (Clark et al. 2015). Collected along a series of transects perpendicular to the thalweg, the DFES data is manipulated using a geographic information system (GIS), gridded to interpolate values between transects, then analyzed to compute sediment thickness (max, mean, accumulation rate) and volumetric statistics.

Even though hydroacoustic mapping has been an important development in being able to accurately determine the amount (Clark et al. 2015, Anderson et al. 2013) and even the type (Elliott et al. 2006) of sediment present in reservoirs, none of these studies has attempted to determine the ultimate fate of the sediments by quantifying the effects of sediment focusing. Sediment focusing involves a variety of processes that all work to redistribute sediments into the deeper zones of a lake. In an attempt to create a conceptual framework for which processes dominate in different lakes, Hilton (1985) provided an overview of many of these processes, including peripheral wave action (PWA) as a dominant force in certain settings. PWA can remove sediment from the shore zone by creating turbulence that resuspends and redistributes the sediment into deeper water (Zakonnov et al. 1999), especially in lakes with significant water level fluctuations (Dirnberger et al. 2005). A review of the water level in Lake Ouachita since impoundment (Figure 1) shows frequent fluctuations of approximately 3 meters, with occasional greater fluctuations.

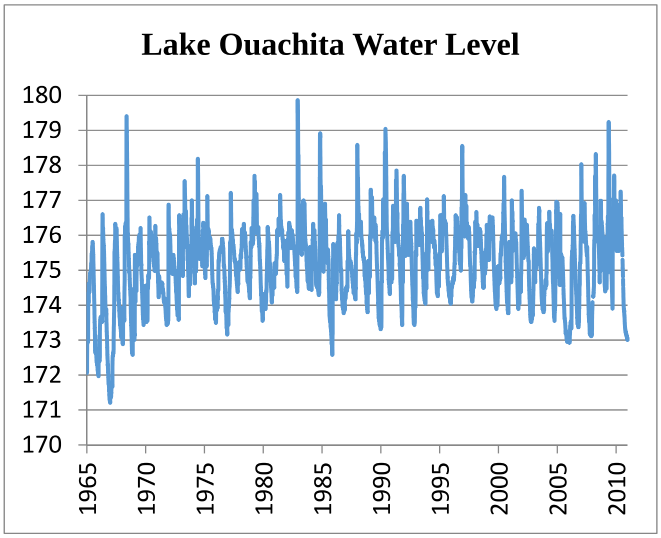

Figure 1. Chart showing water level changes in Lake Ouachita from 1965 to 2011. Elevation data are in meters. Note the conservation pool level is 176.2 m.

This study analyzed the sedimentation patterns where the South Fork of the Ouachita River enters Lake Ouachita (Figure 2). The total sediment volume, linear accumulation rate, and effects of sediment focusing were investigated to better understand the sediment dynamics in this region of the lake where the moving waters of the lotic zone transition into the lacustrine zone of the lake.

Methods

Hydroacoustic mapping using a dual-frequency (24kHz and 200 kHz) echo sounder was utilized to map sediment volumes in June, 2011. The echo sounder (manufactured by Specialty Devices, Inc.) with integrated GPS was mounted to a jon boat and maneuvered along transects perpendicular to the thalweg (pre-impoundment channel) spaced approximately 50 m apart. The boat was driven at a constant speed of 2 m s^{-1} to collect data at approximately 1 meter between locations. Post-processing of the data was performed to interpret pre-impoundment and modern-day bathymetric surfaces using Depthpic v. 4.84 (Specialty Devices, Inc.).

All recorded depths were normalized to elevations using daily lake level data provided by USACE (2016). The resulting X, Y locations and corresponding Z values (bathymetry and sediment thickness) were exported from Depthpic as ascii text files and imported into ArcGIS (ESRI) v. 10.1 for raster interpolation and manipulation.

Calculation of sediment volume and modern-day bathymetry was performed in ArcGIS by using an IDW interpolation technique on the sediment data exported from Depthpic. A series of additional points with a net thickness of 0.0 meters were added to the DFES derived thickness dataset along the lake boundary to minimize edge effects present in most interpolation algorithms (Patton 2008). An output cell size of 10 m was chosen for both the bathymetry and

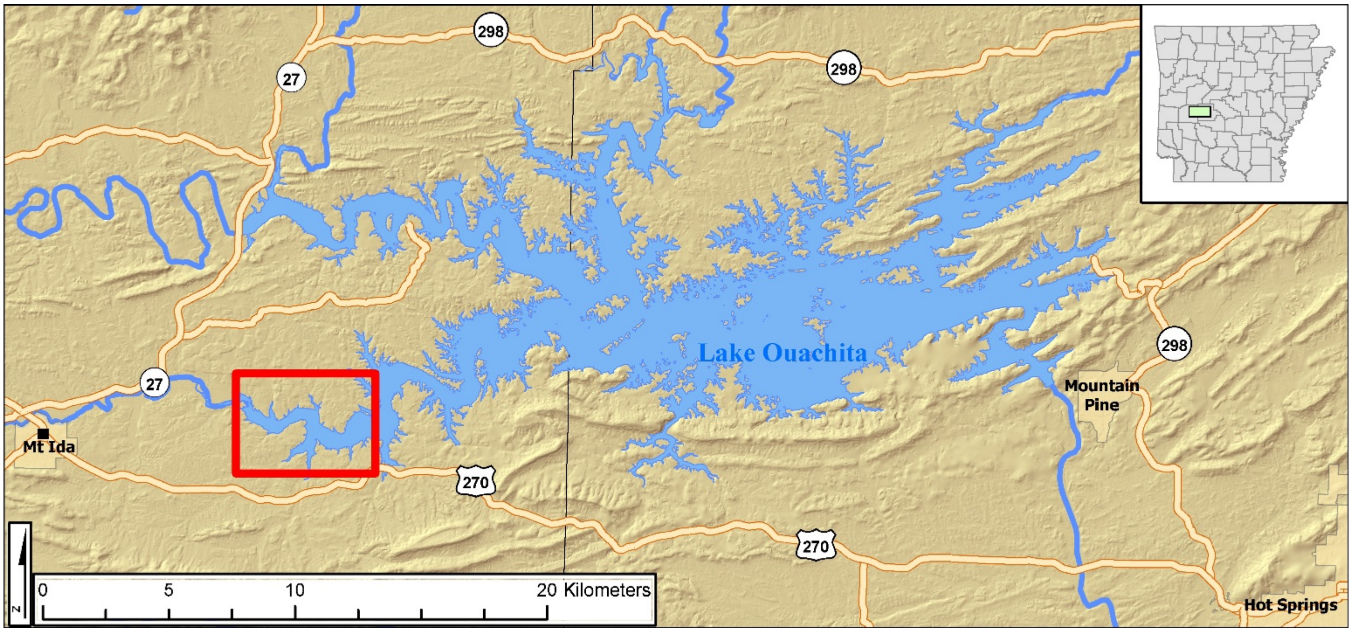

Figure 2. Map showing study area outlined in red. Inset map shows location of Lake Ouachita.

sediment thickness grid. The resulting grids were then clipped using the lake boundary to eliminate from future calculations any grid cells that were interpolated outside of the lake boundary. Simple statistics (max and mean thickness) were extracted from the grid statistics, while the average linear accumulation rate was calculated by dividing the mean thickness by the number of years since impoundment at the time of the study (58 years).

Investigation of the effects of sediment focusing required additional data manipulation techniques. To investigate differences in sediment thickness downslope along the thalweg, the entire study area was divided into three regions (Figure 3). The boundary between the regions was placed at the point where the lake reached a width of approximately 400 meters perpendicular to the thalweg. Regions 1 and 2 are lotic-transitional, while Region 3 is lacustrine. The primary input for Region 1 is the South Fork of the Ouachita River, while Region 2 receives input from the smaller tributaries Shady Creek and Twin Creek. Each of these regions was then further divided into three sub-regions based on water depth. The thickness and bathymetry grids were merged to allow for the zonation of thickness by water depth. Peripheral wave action was assumed to be the primary sediment focusing phenomenon in the study area, therefore the sediment thickness values were divided into three groups based on water depth relative to the conservation pool (176.2 m): <3m; 3-6m; >6m. This division was made based on the observation of frequent water level fluctuations of approximately 3 m below the conservation pool (Figure 1), which would expose that zone to peripheral wave action.

The data from the combined grid was exported from ArcGIS for further processing in Excel (Microsoft), where a simple one-way ANOVA was performed to compare the sediment thickness means of each sub-group.

Results

The average post-impoundment sediment thickness was calculated to be 0.78 m throughout the study area (Figure 3). The maximum sediment thickness was found in Region 3 at 2.93 meters. The total volume of post-impoundment sediment in place was calculated at approximately 2,750,000 m^3 and the average linear sediment accumulation rate was determined to be 1.3 cm y^{-1}. Mean sediment thickness in Regions 1 and 2 were both 0.64 m, while the mean thickness in Region 3 was 0.89 m (Table 1).

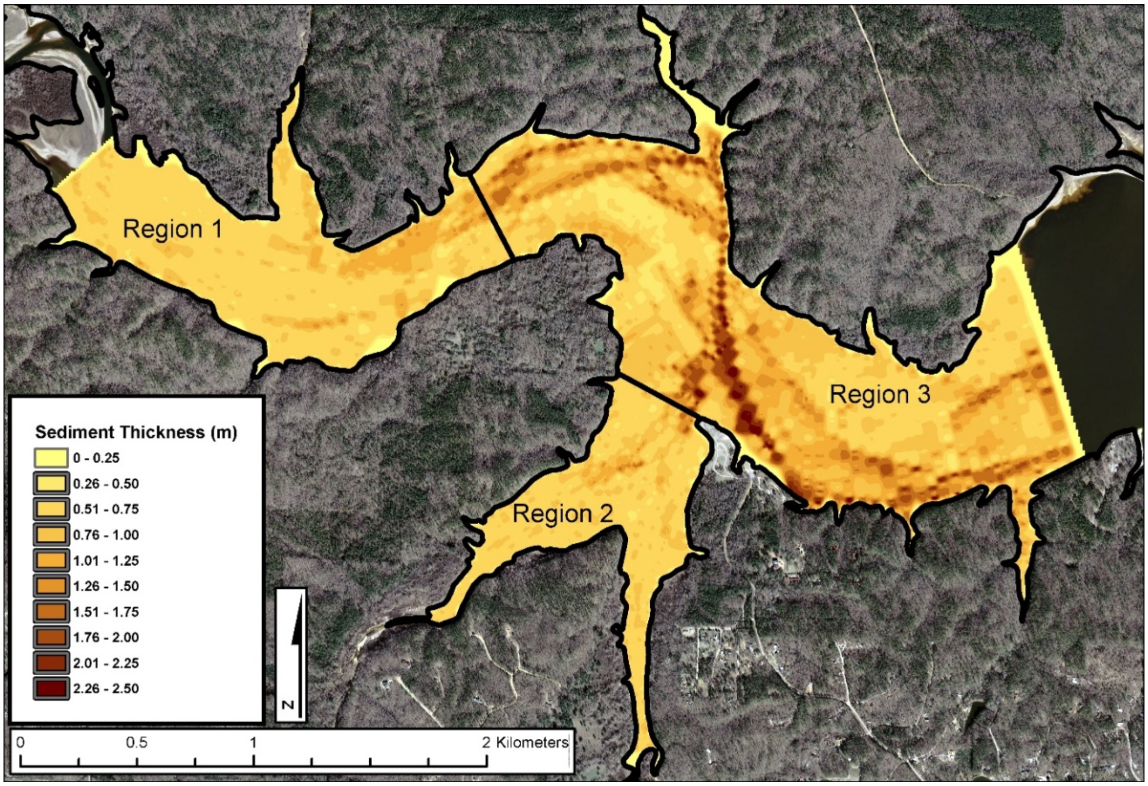

Figure 3. Map showing sediment thickness in three regions.

Table 1. General statistics by region.

	Region 1	Region 2	Region 3
Mean Sediment Thickness (m)	0.6	0.6	0.90
Max Sediment Thickness (m)	1.6	1.9	2.3
Mean Water Depth (m)	2.9	3.3	5.9
Max Water Depth (m)	6.8	8.5	11.8
Total Sediment Volume (m^3)	607,665	373,512	1,772,768
Linear Sedimentation Rate (cm y^{-1})	1.1	1.1	1.5

Further statistical analysis of each region by depth shows some important differences. A simple one-way ANOVA test was conducted to compare the effect of depth on mean sediment thickness in water depths of <3, 3-6, and > 6m. There was a significant effect of depth on sediment thickness at the $p<0.05$ level for the three conditions (see Table 2).

Table 2. Mean sediment thickness in meters in each region by depth. Variance for each mean shown in parentheses. p-Value shown for each region at the bottom of the table.

		Region 1	Region 2	Region 3
Depth	**< 3 m**	0.52 (0.05)	0.53 (0.07)	0.27 (0.12)
	3-6 m	0.75 (0.04)	0.71 (0.02)	0.75 (0.07)
	> 6 m	1.1 (0.04)	0.92 (0.10)	1.14 (0.18)
		p=0.00	*p=0.00*	*p=0.00*

Discussion

Hydroacoustic mapping of bottom sediments in the study area shows an overall sedimentation rate similar to that found in other Arkansas lakes (Table 3), which span a wide range of geologic settings, land use, and reservoir age. Although the linear sedimentation rate in this study (1.2 cm y^{-1}) was on the high end of the range of these studies, it is still low when compared to other regional values.

Analyzing sediment thickness variations by creating regions found some important features. In the two regions that are lotic-transitional (Regions 1 & 2) there was no difference found in the mean thicknesses, which is attributed to the similar depth profile and position. The mean depth of Region 1 was 2.9 m, while the mean depth of Region 2 was 3.3 m. If sediment focusing is continually moving sediment from shallower to deeper parts of the lake, portions of the lake with a similar depth profiles should have similar sediment volumes. Comparing either of these regions with the deeper, more lacustrine Region 3 (mean depth = 5.9 m), shows a dramatic difference in mean thickness and total sediment volume, as would be expected if focusing were occurring.

Statistically significant variations within each region also confirm the presence of sediment focusing. Each region showed the general trend of increasing sediment thickness with increasing water depth. Inspection of the sediment thickness map (Figure 3) shows the thickest sediment accumulations are located in the thalweg, which are by function the deepest parts of the reservoir. Regions 1 and 2 had similar means in each depth range, while Region 3 had a lower mean in the shallow water range. This lower mean in the shallow depths of Region 3 may be related to the steeper topography of the lake bed in that region and the corresponding overall small area of Region 3 in that depth range.

Conclusions

Understanding sediment dynamics in local waterbodies is important for planning and quantifying impacts to the aquatic environment. Hydroacoustic mapping and the zoning by regions can be an effective tool to discover and understand the ultimate fate of sediment. Future research on sedimentation rates in deeper zones of the lake and overall sediment quality (e.g. concentration of trace metals, organic compounds, etc), will allow a better understanding of the full impact of sedimentation to Lake Ouachita.

Acknowledgements

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Table 3. Linear sedimentation rate results from other studies in Arkansas. Studies with asterisk (*) did not directly report linear sedimentation rate. Value calculated by dividing reported average thickness by reservoir age.

	Linear Sedimentation Rate ($cm\ y^{-1}$)
Lee Creek Reservoir (Odhiambo and Boss, 2004)*	1.5
Lake Shepherd Springs (Odhiambo and Boss, 2004)*	0.4
Lake Wedington (Polly, 2001)	0.2
Lake Wedington Repeat (Barnes, 2006)	0.2
Lake Fort Smith (Brown, 2000)	0.3
Prairie Creek Tributary of Beaver Lake (Hansen, 1999)*	1.0
Multiple Tributaries of Beaver Lake (Patton, 2008)	0.5 - 0.7

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Comparison of the Elemental Geochemistry of the Arkansas Novaculite and the Boone Chert in their Type Regions, Arkansas

J. Philbrick*, E. Pollock, and A. Potra

Department of Geosciences, University of Arkansas, Fayetteville, Ar 72701

*Correspondence: jphilbri@email.uark.edu

Running Title: Elemental Geochemistry of the Arkansas Novaculite and the Boone Chert in their Type Regions, Arkansas

Abstract

The name Arkansas Novaculite was proposed by A.H. Purdue, 1909 to replace the name Arkansas Stone assigned by L. S. Griswold, 1892, but deemed too generic, to an interval of Early Devonian-Early Mississippian, very fine-grained, even textured, siliceous sedimentary rock famous for use as whetstones. The interval is exposed along the margins of the Benton Uplift, south flank of the Ouachita Mountains, west-central Arkansas, where it reaches a maximum thickness of 243.8 m (800 ft). The Arkansas Novaculite comprises informal lower and upper members characterized by massive beds of nearly pure novaculite, separated by a shale-bearing middle member that spans the Devonian-Mississippian boundary. The formation represents deep water deposition below carbonate compensation depths, in contrast to contemporaneous chert-bearing intervals, such as the Early Mississippian Boone Formation in the southern Ozarks, with chert formed in shallower marine conditions, or as a replacement of associated limestone beds.

Source of the prodigious quantities of silica forming the Arkansas Novaculite has been controversial. Geochemical analyses, using both EDX and trace element analysis, were performed using mass spectrometry and have identified a significant contribution by both aluminum and potassium, which would seem to eliminate a biogenic origin and favor a volcanic source, perhaps related to an island arc system that formed during the Ouachita Orogeny as Laurasia collided with Gondwana. Trace element analysis also suggests that the Arkansas Novaculite and the chert in the Boone Formation may have both been formed from the same volcanic source.

Introduction

Deposition of the Arkansas Novaculite, named by Purdue (1909), began during the Early Devonian, possibly even Silurian (Lowe 1985), and continued through the Kinderhookian Series, Early Mississippian. It is bounded stratigraphically by gradational contacts between thick shale intervals referred to the Missouri Mountain Shale and Stanley Group at the base and top, respectively. The Arkansas Novaculite has been divided into numerous named members and submembers (Miser and Purdue 1929), but regional application of that nomenclature is questionable. This study examines the major and trace elements of informal lower, middle, and upper members of the formation, and did not differentiate between novaculite and chert. All Arkansas Novaculite samples were taken from the well-known Caddo Gap roadcut, located on the southern flank of the Benton Uplift, the structural core of the Ouachita Mountains in east-central Arkansas.

The source of the silica for both the Arkansas Novaculite and Boone chert has generated considerable debate, although there has been little comparison of the two intervals. Most studies of the Novaculite (Sholes and McBride 1975 is typical), and Boone and other chert-bearing intervals (see Hesse 1990 for a review) cite altered siliceous bioclastic remains, commonly sponge spicules, as the silica source. However, other proposed origins for the Novaculite silica include simultaneous dissolution of limestone and precipitation of silica (Rutley 1894, Derby and Banner 1898, Correns 1950), volcanic ash deposited in a sediment-starved basin (Goldstein and Hendricks 1953), and hydrothermal alteration of quartz sandstone (Owen 1860, Comstock 1888). Tarr (1926) hypothesized direct precipitation of silica as a colloidal sol derived from terrestrial erosion and transported to marine environments by rivers and streams for the Boone and other midcontinent chert.

Geologic Setting

Paleozoic Area of Arkansas

The Paleozoic area of Arkansas comprises three

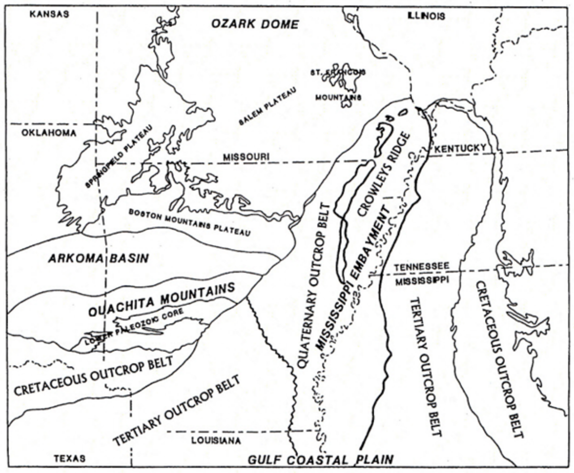

Figure 1. Geologic Provinces of Tri-State area Ouachita Mountains. (Modified from Manger et al. 1988)

geologic provinces, from north to south: the south flank of the Ozark Dome, Arkoma Basin and Ouachita Mountain orogenic belt (Figure 1). The Ozark Dome is a broad, asymmetrical, cratonic uplift cored by Precambrian granite and rhyolite, with Upper Cambrian to Middle Pennsylvanian strata dipping radially away from the core area. The area lacks structural complexity, compared to the Arkoma Basin and Ouachita Mountains. A series of *in echelon* normal faults striking northeast-southwest and downthrown to the southeast extends across the southern Ozarks, and the regional dip averages only 19′ (Chinn and Konig 1973). Three broad plateau surfaces reflect periodic epeirogenic uplifts. From oldest and lowest elevation, these are the Salem, Springfield, and Boston Mountains Plateaus. The Salem Plateau comprises Lower Ordovician limestones and dolomites with the largest aerial extent in the region. The Springfield Plateau forms the Eureka Springs Escarpment, and is capped by limestone and chert of the Lower Mississippian St. Joe Limestone and Boone Formation. The Boston Mountain Escarpment and its Plateau are the youngest and highest surface in the Paleozoic area of Arkansas formed by Upper Mississippian through Middle Pennsylvanian (Atokan) strata.

The Ouachita Mountains are an east-west trending anticlinorium of Paleozoic rocks extending across west-central Arkansas into southeast Oklahoma. The Ouachita orogenic belt has been subdivided into the Arkoma foreland basin, separating the Ozarks and Ouachitas, the frontal imbricated zone, central thrust belt, and the Benton and Broken Bow Uplifts (Arbenz 1989). The frontal fold-thrust belt of the Ouachitas is north vergent, excluding the cores of the Benton and Broken Bow Uplifts, and forms the southern margin of the Arkoma foreland basin (Arbenz 1989). Strata forming the Ouachita Mountains are dominated by deep-water facies, beginning as a starved basin from the Late Cambrian through the Early Mississippian followed by flysch sedimentation characterizing the Upper Mississippian through Middle Pennsylvanian (Arbenz 1989). The structure is the result of a collisional-subductional orogeny between Laurasia and Gondwana during the late Paleozoic era (Lowe 1975).

Lithostratigraphy and Sequence Stratigraphy

Tri-State Area

This study focuses on the Lower Mississippian transgressive-regressive sequence represented by the St. Joe (Hopkins 1893) and Boone (Branner 1891) Formations in northern Arkansas, particularly peneontemporaneous chert in the lower Boone. This succession reflects transportation of carbonates sourced from the Burlington Shelf, in what is now Missouri, which were deposited frequently as condensed intervals down ramp in northern Arkansas. This ramp developed extensively along the southern margin of the North American Craton. The names St. Joe and Boone were taken from exposures in northern Arkansas and are the oldest, valid lithostratigraphic designations for their respective intervals. The name St. Joe was proposed (Hopkins 1893) as the basal, chert-free limestone member of the thicker, potentially >121.9m (400ft), chert-bearing Boone Formation (Giles 1935).

The Lower Mississippian St. Joe-Boone interval represents a single, third-order, transgressive-regressive, eustatic cycle. It is a portion of the first-order Kaskaskia sequence recognized by Sloss (1963) that extended from the Early Devonian to the Mississippian-Pennsylvanian boundary, and has been subdivided into second-order Kaskaskia I and Kaskaskia II Cycles (Witzke and Bunker 1996). The Kaskaskia I second-order cycle began in the Early Devonian and extended to the Devonian-Mississippian boundary, while the Kaskaskia II second-order cycle encompassed the entire Mississippian. The Early Mississippian third-order cycle includes the Kinderhookian-Osagean interval (Witzke and Bunker 1996), which comprises the St. Joe-Boone carbonates in northern Arkansas. -Initial transgression of this third-order cycle is represented by the St. Joe interval, which spans the Kinderhookian-Osagean boundary. Maximum flooding occurred in the lower Boone, while high-stand and regression encompass the upper Boone

Formation (Manger and Shelby 2000).

Ouachita Mountains

The name Arkansas Novaculite as a lithostratigraphic name was proposed by Purdue (1909), to replace the name Arkansas Stone assigned by Griswold (1892), as a lithologic term that also included the Middle-Late Ordovician Big Fork Chert. Lithologies of the Arkansas Novaculite can be divided into northern and southern facies described originally by Miser and Purdue (1929). Lowe (1977) applied the term northern facies to describe the black chert, shale, sandstone, siltstone, and chert-shale pebble conglomerate and breccia of the northern exposures. The southern facies of Lowe (1977) comprises the better known distribution of the massively bedded, white novaculite, which is more commonly thought of as the Arkansas Novaculite lithostratigraphic entity. The southern facies was divided into three unnamed members (Miser 1917), described as the lower and upper novaculite members, separated by a middle member of chert and shale. Further subdivisions were proposed by Lowe (1976) at the Caddo Gap road cut, sampled for this study, that include (ascending order) the lower chert-and-shale, calcareous novaculite, translucent novaculite, massive novaculite, and breccia subdivision. The middle member was subdivided by Lowe (1989) into three divisions: a lower bedded black chert and shale, ~50-70 m thick; a middle shale, ~14 m thick; and an upper chert and shale interval, ~20 m thick. The upper member is predominately white or light gray, highly weathered novaculite (Lowe 1989). The upper member includes enough calcium carbonate that it develops porosity from weathering, which has been exploited for tripoli (Cornish 1997).

The two second-order Kaskaskian cycles also play a major role in the depositional dynamics affecting the Arkansas Novaculite. The transgressive cycle represented in the lower novaculite member caused craton margin submergence that limited detrital influx by trapping it close to shore producing nearly pure novaculite in a deep sea setting (Lowe 1976). A second order regression seen during the Upper Devonian produced the middle novaculite member, with interbedded shales brought into the deep basin from the exposed shelf by the retreating seas. This terrigenous influx suppressed pure novaculite deposition, but enough silica remained in the system to produce chert. The Kaskaskia II cycle produced a return of transgressive seas across the craton during the Kinderhookian and beginning of the Osagean Series (Sloss 1963). Consequently, the upper novaculite member represents a return to siliceous rock deposition, but with a carbonate contribution as a deeper water setting returned.

Geochemistry of the Arkansas Novaculite and Lower Boone Chert

Sample Collection, Preparation, and Analysis

Arkansas Novaculite samples were collected at the Caddo Gap road cut along Highway 27 through nearly 274.3m (900 ft) of vertical to near vertical beds of the southern facies. Samples were collected at 3.05m (10 ft) intervals from the exposed base of the outcrop to the top exposure at the presumed contact with the Stanley Group. Weathering of the middle member prevented the acquisition of field samples from that interval. Samples of the penecontemporaneous chert of the Boone Formation were collected from the Bella Vista road cut along the off-ramp, where I-49 joins U.S Highway 71B on the south side of Bella Vista, Arkansas.

Samples from both intervals were taken from the field, washed using deionized water, and allowed to air dry. Samples for geochemical study were slabbed using a miter saw attached with a diamond-edged blade. Three cuts were made on each sample in order to self-contaminate the blade. The third slab was then washed with double distilled water to remove any possible contamination from the saw table and again allowed to air dry. Dry slabs were wrapped individually, and broken into small flakes and pieces suitable for powdering with a rock crusher, and for EDX analysis.

Powdered samples were dissolved using a MARS 5 (CEM Corp., Matthews, NC) microwave digestion system. Approximately 0.5g of sampled material was placed in a 55ml digestion vessel. Digestion utilized concentrated acids: HNO3 (3ml), HCl (2ml), and HF (5ml). Samples were ramped to 200^{o} C and held for 15 minutes. Following digestion, the acids were neutralized using a 4% by volume boric acid solution in compliance with the HF neutralization method. The neutralized samples were then subjected to a 10x dilution before trace element analysis was performed using the iCAP Q ICP-Mass Spectrometer. The elemental suite chosen for this study was based on the Kelemen, Hanghøj, and Greene (2003) study of subduction-related magmatic arcs.

Small flakes of each sample undergoing trace element analysis were taken from the slabbed samples prior to powdering, and broken into smaller pieces with an emphasis on exposing a fresh surface for analysis.

Table 1: Average concentration of trace elements and rare earth elements (REE) for the Arkansas Novaculite, its enriched and depleted U groups, and the Boone Formation.

Trace Element and REE Average Concentration Values (ppm)

	Be	**Al**	**K**	**V**	**Cr**	**Mn**	**Co**	**Ni**	**Cu**	**Zn**	**Ga**	**As**	**Rb**	**Cd**	**Cs**	**La**	**Ce**
Novaculite Average	3.08	9333.94	983.40	69.04	16.26	111.23	4.62	9.35	22.19	14.77	4.51	3.73	17.60	0.12	1.72	9.09	15.94
Novaculite Average 50-69	4.25	24344.69	2295.15	164.17	40.72	47.76	4.60	20.27	47.22	25.41	10.11	7.75	43.72	0.24	4.16	16.61	29.25
Novaculite Average others	2.44	6279.59	277.08	1.77	3.09	145.40	4.62	3.47	8.71	9.04	1.50	1.56	3.53	0.05	0.41	5.03	8.78
Boone Averages	1.83	10526.91	776.50	3.74	5.16	79.07	2.73	3.28	1.74	5.84	1.22	0.72	3.21	-	-	3.37	3.52
	Pr	**Nd**	**Sm**	**Eu**	**Gd**	**Tb**	**Dy**	**Ho**	**Er**	**Tm**	**Yb**	**Lu**	**Hg**	**Tl**	**Pb**	**Th**	**U**
	2.66	9.46	1.50	0.59	2.41	210.96	2.50	0.52	1.46	0.21	1.37	0.23	0.02	0.19	11.36	2.28	3.02
	5.19	18.28	2.93	1.15	4.56	386.04	4.42	0.90	2.51	0.37	2.45	0.41	0.06	0.45	22.12	4.70	7.46
	1.29	4.71	0.74	0.29	1.25	116.68	1.47	0.32	0.89	0.13	0.79	0.13	0.00	0.05	5.57	0.98	0.62
	0.49	2.96	0.31	-	0.35	64.23	0.31	-	0.10	-	0.05	-	0.00	0.05	2.40	0.10	0.42

Samples were placed on carbon tape to adhere to the microscope stage, sputter coated with gold and examined by EDX using a FEI Nova Nanolab 200 Dual-Beam microscope.

EDX analysis of the Arkansas Novaculite and lower Boone chert reveals elevated levels of aluminum that can only be explained by derivation of the material from an igneous source. Elevated aluminum levels were found throughout the sampling for both units, usually ranging between 0.35 wt % and 2.0 wt %. Two samples of Arkansas Novaculite (50A and 50B) that were not representative of the massive white novaculite also exhibited elevated levels of aluminum (Al). This is attributed to their incorporation of aluminum silicate clay minerals producing their dark black and light gray colors respectively. Additional elements that showed anomalous spikes in the EDX spectrum were magnesium (Mg), sodium (Na), iron (Fe), calcium (Ca) and potassium (K). The weight percentage of these elements ranged from 0.02 wt % to 0.72 wt %. However, these weight percentages are suppressed by the inclusion of gold from the coating for EDX in the analyzed spectrum. Trace element and REE data (Table 1) were normalized to the values of average primitive arc andesite of continental and Aleutian arc types compiled by Kelemen et al. (2003) in order to verify which kind of volcanic source was contributing the silica to the Ouachita Basin and its northern shelf and ramp settings. Kelemen et al. (2003) compiled geochemical data from various public sources as well as their own research in order to form a comprehensive analysis of the composition of subduction related magmatic bodies. The study defined andesite as magmatic compositions with >54 wt. % SiO_2. The majority of normalized values regardless of arc type plotted between 10 and 0.1 on a log scale (Figure 2).

Discussion

Paleogeographic reconstructions by Morris (1974) and Lowe (1975) present two differing interpretations of the convergent boundary located to the south of the Novaculite and Boone Formation depositional sites. Lowe (1975) proposed a volcanic island arc system with surface wind and ocean currents pushing pyroclastic debris north into the Ouachita Basin. Morris (1974) placed a microcontinent to the south of the basin. With these two interpretations in mind, the geochemical data obtained in this study were normalized to REE concentration averages of both continental and Aleutian magmatic arc systems as

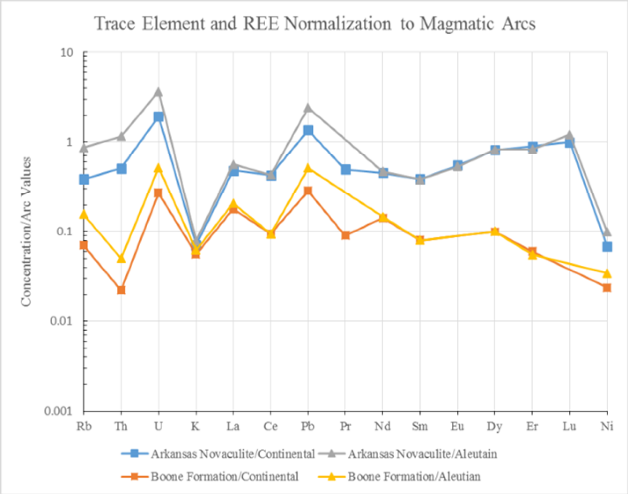

Figure 2: Elemental concentrations normalized by average continental and Aleutian values.

presented by Kelemen et al. (2003). The Arkansas Novaculite and Boone Formation chert were both under saturated in REEs in comparison to the igneous bodies, which would be expected. The generally low concentrations of most trace elements and REEs are interpreted to be due to the lack of clay incorporated into both the Arkansas Novaculite and Boone Formation chert. Most of the REE compositions of siliceous deposits are found in its incorporated silt and clay sediment and the quartz REE concentrations are usually very low (Cullers et al. 1979). Trace element and REE concentrations found in the Arkansas Novaculite compare favorably to volcanically sourced chert within the Nicoya Complex of Costa Rica analyzed by Hein et al. (1983). In particular the average values found within the Nicoya Complex for Co (3.38), La (15.8), Be (1.14), Cr (15.1), and Pb (8.1) are analogous to average values for the Arkansas Novaculite, Co (4.62), La (9.09), Be (3.08), Cr (16.26), and Pb (11.36).

Elevated levels of Al and to a lesser extent Fe, Na and K support the conclusion that a source inherently rich in these elements played a major role in the siliceous sedimentation. Analysis of early diagenesis of chert and chemical fractionation by Murray (1994) provides evidence that Al, Fe and REEs are immobile into or out of the silicate crystalline framework. These two elements as well as potassium are an indicator of volcanic contributions (Murray 1994, Hein et al. 1981), which would have been present in the Paleozoic ocean during the time of deposition for these formations (Lowe 1975).

When comparing the geochemistry of siliceous deposits in the Arkansas Novaculite and Boone Formation, it is clear that the Novaculite is much more enriched in trace elements and REEs. This is consistent with the conclusions of Murray (1994) that exposure time to seawater influences the chemistry of chert and that as sedimentation rates increase the amount of REEs incorporated from the seawater decreases. This water would have been enriched in REEs by the volcanic activity to the south. The dramatic increase in sedimentation rates during deposition of the Boone Formation would have quickly buried the penecontemporaneous chert, which originally developed below the sediment water interface, and initiate lithification and dewatering of the surrounding sediment. Two indicators of a volcanic influence align, Al and K. The general trends of the normalized data (consistent values across the suite of elements except the relative enrichment in uranium and lead, and depletion of nickel relative to the other elements analyzed) are consistent for both formations as well. These relationships are key to the conclusion that the Arkansas Novaculite and the penecontemporaneous chert of the Boone Formation represent silica sedimentation from a similar volcanic source.

Acknowledgments

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History and Fall Migration of Northern Saw-whet Owls (*Aegolius acadicus*) in Arkansas

M.L. Pruitt* and K.G. Smith

Department of Biological Sciences, University of Arkansas, Fayetteville, AR 72701

*Correspondence: mlpruitt24@yahoo.com

Running title: Northern Saw-whet Owls in Arkansas

Abstract

The secretive Northern Saw-whet Owl (*Aegolius acadicus)* is believed to be much more widespread during fall and winter than previously thought in the southern United States. To see if they occur more frequently in Arkansas, we initiated a banding study in fall of 2014 in northwestern Arkansas. Prior to that, only 12 historic records existed for Arkansas between 1959 and 2010. Over the course of two field seasons, we captured and banded 24 Northern Saw-whet Owls in rural Madison County. All birds were mist-netted along a trail, in woodland composed of pine and cedar with fairly dense undergrowth. Two were captured during our 2014 season when we started in late November and 22 were captured between late October and early December in 2015. We also had at least 10 birds vocalizing at our site. It would appear that the peak of migration in Arkansas is late October through early November, with capture rates dropping off by early December. All but one of the captured birds were females, the most common sex this far south. There was a fairly even distribution of hatch-year, second-year, and after-second-year birds and hatch-year birds and adults arrived at about the same time in late October and early November in 2015. Exactly where the owls are migrating from is unknown, although three foreign recoveries in Missouri and four recoveries in Arkansas suggest they are coming from the western Great Lakes region. Once considered a vagrant, based on our research, the Northern Saw-whet Owl appears to be an uncommon fall migrant, at least in the northwestern part of Arkansas. Comparing our data with that for central Missouri, about the same number of birds were captured at the same rates for about the same length of time, suggesting that Northern Saw-whet Owls are probably more common in the Ozarks than previously thought.

Introduction

In eastern North America, Northern Saw-whet Owls (*Aegolius acadicus*; hereafter “saw-whet”) are primarily a denizen of the boreal forests of Canada and mountainous forest of Appalachia during the breeding season, but birds migrate south in fall into the United States (Confer et al. 2014), sometimes in large “invasions” (Brinker et al. 1997, Whalen and Watts 2002, Brittain et al. 2009). However, their distribution is poorly known in the southern United States. Recent attempts to capture birds during fall migration have been successful in Missouri (D. Ripper, *unpubl. data*), Alabama (R. Sargent, *unpubl. data*), and Georgia (Muise 2009), as was an earlier attempt in South Carolina, primarily in 1999 (W. Hilton, *pers. comm.*).

The first mention of a saw-whet in Arkansas was made by Howell (1911) although he doubted the authenticity of the report based on time of year. Since he worked closely with the National Museum at the Smithsonian Institute in his capacity as a scientist for the Bureau of Biological Survey in Washington, D.C., he knew of the report of a specimen of a saw-whet attributed to the Whipple Expedition from Fort Smith in early July of 1853. This specimen is indeed listed in the catalog of the museum (number 3891), but the specimen has been lost (Howell 1911; B. Schmidt, *pers. comm.*). The Whipple Expedition was one of several expeditions to find the best route for the railroad to extend to the West Coast and traveled through what is today Oklahoma, Texas, New Mexico, Arizona, and California. The major collector for the trip from Fort Smith to Albuquerque was Heinrich Balduin Möllhausen, but the missing specimen is attributed to the leader, Lt. Amiel Weeks Whipple, according to the Smithsonian catalog. There is no date associated with that record, but the expedition spent about 2 weeks in Fort Smith before departing on 15 July (Wright and Shirk 1949).

There is little support for the saw-whet record associated with the Whipple Expedition, reported by Howell (1911). It was the middle of summer, the specimen has been lost, and there is no mention of this bird in the report of the birds collected on the Whipple Expedition (Kennerly 1859). [Kennerly (1859) did mention a Carolina Parakeet (*Conuropsis carolinensis*) and a Yellow-crowned Night-Heron (*Nyctanassa violacea*) collected by Möllhausen from Fort Smith and they are both in the collection of the National Museum (B. Schmidt, *pers. comm.*).] Baird summarized results of all birds collected on all railroad expeditions and did not mention a saw-whet from the Whipple Expedition (Baird 1858:58). He did mention a saw-whet from "Texas" collected on the Pope Expedition, which was the route south of the Whipple route. This specimen is also listed in the Smithsonian catalog (number 5039), but it too has been lost (B. Schmidt, *pers. comm.*).

Between 1959 and 2010, there were 12 reports of saw-whets in Arkansas that involved a sighting or a specimen, according to the records maintained by the Arkansas Audubon Society (AAS), most of which occurred in November and December (Fig. 1). These records are scattered, but mostly north of the Arkansas River, with an emphasis on the Ozarks, Crowley's Ridge, and around Little Rock (Fig. 2). The first specimen was a road-killed owl found by Trusten Holder, an Arkansas Game and Fish Commission employee, on 11 November 1959 in Reydell (Jefferson County). This unsexed specimen is in the University of Arkansas Museum (UAFMCZ 0085-0078-1802). A second specimen, also a road kill, was found by Keith Sutton, the noted outdoors writer, on 22 November 1976, 1.6 km north of Harrisburg (Poinsett County). At the time, Sutton was an undergraduate at Arkansas State University and gave the specimen (AAS verification doc. #389) to Earl Hanebrink, the ornithologist there, who made a study skin of the bird. This specimen has apparently been lost as it is not in the Arkansas State University collection. While investigating the collection at the University of Arkansas Museum, another heretofore unreported specimen was discovered from Fayetteville (Washington County). The bird was found along Tilly Willy Creek south of town, on 4 December 1993, with a broken wing and was taken to a rehabilitation facility where it died on 21 January 1994. Then graduate student T. Scott Sillett prepared the study skin (UAFMCZ 0094-0009-0004) of the female owl.

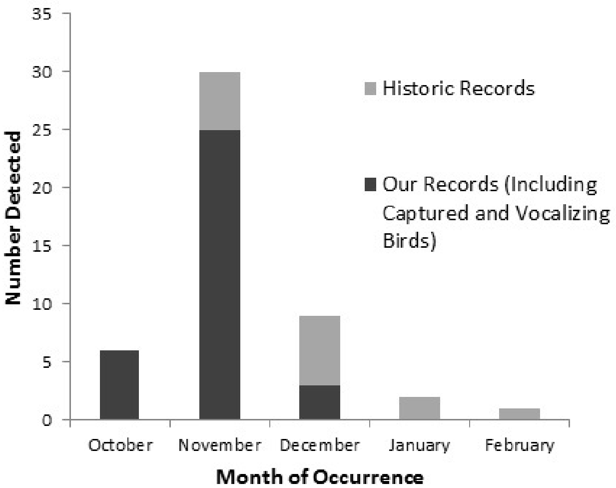

Figure 1. Arkansas saw-whet owl records from 1959 through 2015 by month. The historic records are from the Arkansas Audubon Society database and include the two game-camera records from Madison County in December 2014 and January 2015 mentioned in the text.

Figure 2. Distribution of the first 12 records from Arkansas with the month and year of each sighting. ONSC refers to the location of our study site. Note that most sightings are associated with heavily forested areas on the background map. Four records and our study site are in the Ozarks (upper left) and 3 records are on Crowley's Ridge (upper right).

Three other birds were found and taken to rehabilitation centers. On 25 November 1975, an injured bird was reported from North Little Rock (Pulaski County). It was taken to a veterinary clinic, where it died on 2 December. On 30 December 1999, a bird was captured by a dog patrol in West Memphis (Crittenden County) and taken to Knox Martin, a rehabilitator in Memphis, Tennessee. He fed the bird mice and released it on 3 January 2000. On 4 November 2005, Lynn Slater found a bird that had been hit by a car north of London on the Pope/Johnson County line. It was photographed in rehabilitation (AAS files), recovered, and was released in Wisconsin during spring of 2006 (L. Slater, *pers. comm.*).

Two of the reports were foreign recoveries of birds banded elsewhere. The first was a bird "caught by hand" by Roman J. Selig, Jr., on 12 December 1969, 6.4 km north of Rector (Clay County). The bird had been banded (U. S. Fish and Wildlife band 574-45418) the previous month, on 14 November 1969 at Cedar Grove (Sheboygan County), Wisconsin, by Daniel D. Berger. The distance between those 2 sites is 840 km, indicating the bird averaged at least 30 km/night. The second banded bird was brought by a dog to its owner on 23 February 1992, 9.6 km south of Paragould (Greene County) on Highway 49. It had internal injuries and a broken wing and eventually was given to Karen Rowe, a wildlife biologist with the Arkansas Game and Fish Commission. She gave it to Heath Garner, a rehabilitator in Jonesboro, but the bird subsequently died that night and the specimen was destroyed. The bird had been banded (0614-45855) as an adult female by W. N. Grigg on 9 October 1990 near Stonington (Delta County) on the Upper Peninsula of Michigan.

Of the remaining 4 records of saw-whets in Arkansas, 3 were sightings of single birds and one was a photograph. The first was a bird found by Douglas A. James, ornithologist at the University of Arkansas, and then student H. H. (Hank) Shugart, Jr., at Shores Lake (Franklin County) on 30 January 1967. Donna O'Daniel, a birdwatcher, reported one at her residence in the Crumpler Subdivision (Boone County) on the upper Bull Shoals reservoir near the Arkansas/Missouri border on 25 December 1997 (AAS verification doc. #900). A third sighting occurred predawn with a flashlight while Jack and Pam Stewart were owling during the Crooked Creek Christmas Bird Count at the Erbie (Newton County) campground within the Buffalo National River on 15 December 2010. Larry Obsitnik, a photographer for the Little Rock newspaper, *Arkansas Gazette*, took a picture of a saw-whet sitting on a "no parking" sign during the day in Little Rock, on 7 November 1969, and it appeared on the front page on 8 November. Douglas James obtained a copy of the photograph for the AAS files (Fig. 3).

The objective of our study was to attempt to document occurrence of saw-whets in Arkansas during fall migration and winter, using mist-nets and audio lures for the first time. Prior to our research, saw-whets were considered a rare bird within the state of Arkansas (James and Neal 1986). James and Neal (1986) concluded that due to their nocturnal habit and secretive nature, saw-whets might be more common in the state than records suggested. Nonetheless, our expectation was that we would capture no saw-whets.

Figure 3. Photograph of saw-whet taken by Larry Obsitnik that appeared on the front page of the *Arkansas Gazette* the following day, on 8 November 1969. He had no idea what the owl was and was making a joke about the owl not being able to read the sign. Douglas James identified the bird from the picture in the newspaper and obtained a copy of the picture for the AAS files. (Photo courtesy of Lyndal York)

Methods

Our research used standard methods developed by a group of researchers in the northeastern United States (Project Owlnet 2016). We used four 12m mist nets with 60mm mesh, an audio lure to draw birds into the net area, and tools for processing upon capture. A typical night consisted of being in the field from 1900 until 0000 hours or later.

Our field station was located at the Ozark Natural Science Center (ONSC) in rural Madison County, Arkansas, where the habitat is a mixture of pine and deciduous upland with a thick cedar understory, the apparently preferred habitat of saw-whets (Brittain 2008). ONSC is a residential nature center on property owned by the Arkansas Natural Heritage Commission, imbedded in the McIlroy Madison County Wildlife Management Area, administered by the Arkansas Game and Fish Commission.

Four mist nets were arranged in a line down a trail through cedars adjacent to the main parking lot of the center. The audio lure was placed at the center of this arrangement and played continuously during time afield. The use of an audio lure began in 1986 as a method to increase saw-whet captures (Erdman and Brinker 1997). Our lure was played on a predator caller (Cabela's Outfitter Series, FoxPro, Lewistown, PA) programmed with several call types of saw-whets from Stokes and Stokes (2010). Call types played included the breeding male's *toot, toot, toot* (18 sec) as well as an "excited" male call (3 sec) and a whine call (8 sec), which is often given during migration (Weidensaul 2015). Those 3 calls were played continuously with a 6 sec break between bouts. No netting was conducted on nights deemed to be too windy (> 24.2 kph) or too cold (< -5 ^{o} C).

In 2014, netting began on 19 November and continued sporadically through January into early February of 2015. In fall of 2015, netting began on 18 October and ended on 3 December. Nets were checked every 45 minutes.

Upon capture, a bird was taken inside a building for processing, which involved sexing, ageing, and banding the bird. Sexing of saw-whets was done by comparing a bird's closed wing chord and its mass using the chart published by Brinker (2000). All birds were weighed in a mesh banding bag using a Pesola spring scale.

Ageing saw-whets was done using ultraviolet (UV) light to fluoresce porphyrin pigment on the ventral surface of flight feathers (Primaries: P1-P10; Secondaries: S1-S12). In saw-whets, this pigment is pink when fluoresced by UV "black" light. Once exposed to sunlight, porphyrins begin to fade making different ages of feathers fairly distinct. New feathers fluoresce bright pink, middle-aged feathers are light pink, and old feathers may not show any pink (Weidensaul et al. 2011). Three distinct age classes can be identified using this method (Fig. 4). Hatch-year (HY) birds have flight feathers of a single age. Second-year (SY) birds have two distinct ages of flight feathers. After second-year (ASY) birds have three or more distinct ages of feathers (Pyle 1997). After a saw-whet's second year, its age cannot be identified more specifically unless it was previously banded. Finally, captured birds were banded using a size 4 (short) federal band, and released into the night.

Capture rates were calculated for the fall 2015 banding season based on birds captured per 100 net-hours, the standard way of reporting banding effort for saw-whets. Typically, 4 nets were open for 4 hours each night, or 16 net-hours per night. The season capture rate was calculated from the night of the first capture (28 October) to the night of the last capture (21 November).

Results

Over the course of two field seasons, a total of 24 saw-whets were captured and banded at the Madison County field site. In 2014, netting efforts did not begin until 20 November due to issues in obtaining all

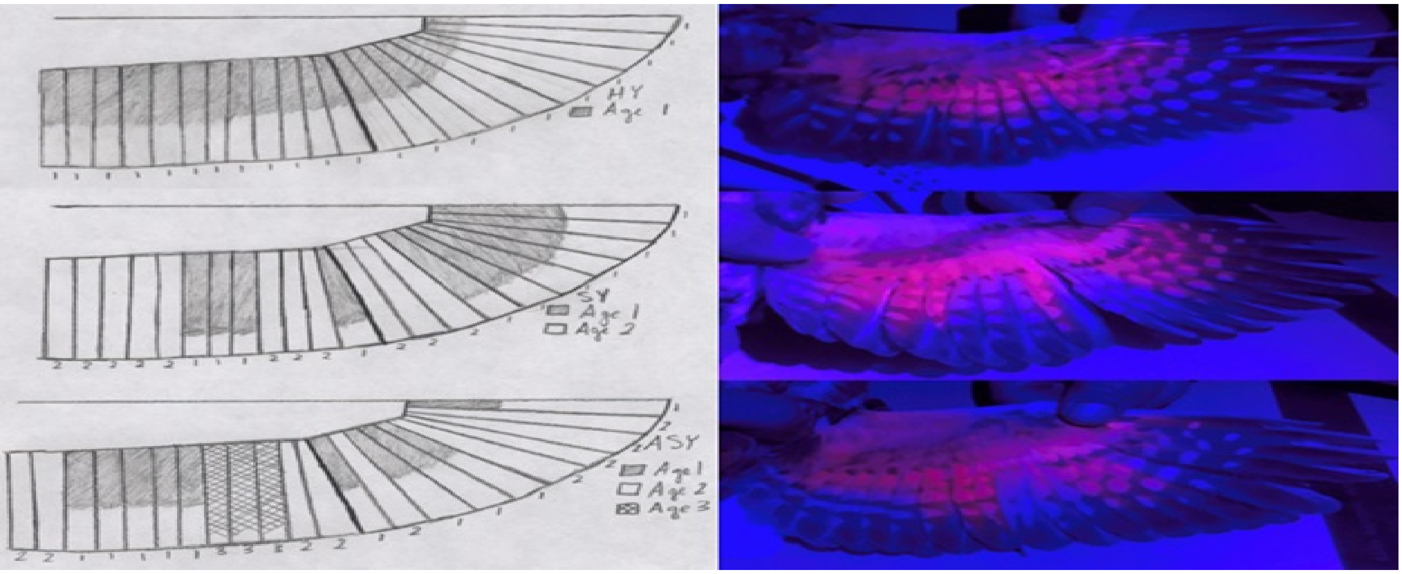

Figure 4. Age classes of the saw-whets based on fluorescence of porphyrin on the underwing. Top: hatch-year bird with uniform color indicating that all feathers are new. Middle: second-year bird with 2 different colors of feathers: new feathers are bright while second-year feathers are faded. Bottom: After second-year bird with 3 different colors of feathers: new feathers are bright, second year feathers are paler, and third year feathers barely fluoresce.

necessary permits from federal and state agencies. Even so, two individuals were captured. The first saw-whet was captured on 21 November and was in the company of another individual that was not captured. (Two birds were vocalizing simultaneously at the nets 30 min prior to the capture.) Another individual was captured on 7 December. Efforts continued through January 2015 and sporadically into February with no captures or vocal detections after the first week of December. Our second field season began earlier in fall of 2015 in October, and continued through 3 December. During this time, 22 saw-whets were captured and banded (Fig. 5). The 2015 field season consisted of 23 total nights afield, or 257.3 total net hours. Of these 23 nights, 10 nights had captures (43.5%) and five birds were captured on the night of 6 November after the passage of a cold front.

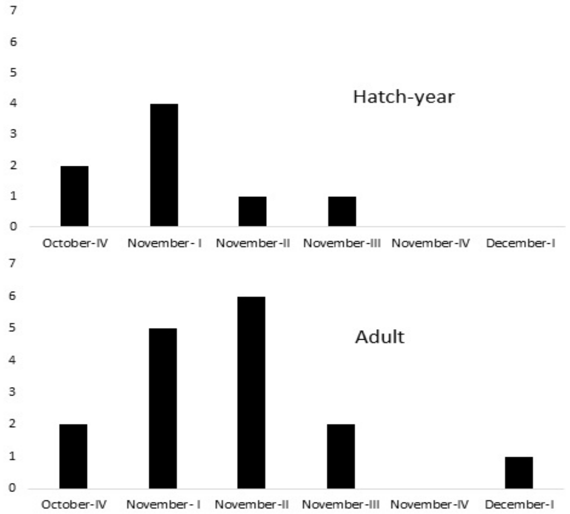

Figure 6. Number of arrivals of hatch-year and adult saw-whets by week from the 4th week of October through the first week of December combining 2014 and 2015.

The sex ratio was heavily skewed towards females. Only one individual of the 24 captures was identified as a male. The single male was captured 21 November 2015 and was aged as a hatch-year bird. The male had a closed wing chord (CWC) of 136mm and weighed 80g. The average CWC of captured 23 females was 141.9mm (0.57 SE) with a range of 138-146mm. The average weight of captured females was 90.9g (1.16 SE) with a range of 80-105g. The age distribution was fairly even between the three identifiable classes: HY (33%), SY (29%), ASY (33%), and fourth year (4%). A saw-whet captured on 7 November 2015 at ONSC was banded as a SY bird at the Linwood Springs Research Station near Stevens Point (Portage County), Wisconsin on 17 October 2013, meaning it was in its fourth year when captured at our field site. Hatch-year birds arrived at about the same time as adults (Wilcoxon sign-rank test, W = 72.5, P = 0.27; Fig. 6).

The capture rate for 2015 was 8.6 birds per 100 net-hours. Records from this research were compared to Arkansas's historic records and show a peak in migration during the first two weeks in November (Figs. 1 and 5). Interestingly, most of the captures seemed to occur during the hours of 2100-2200 and again around midnight (Fig. 7).

During the 2015 season, two birds were foreign recaptures, meaning they were banded somewhere other than our ONSC field site. The first was the aforementioned 4-year-old bird banded (0914-53397)

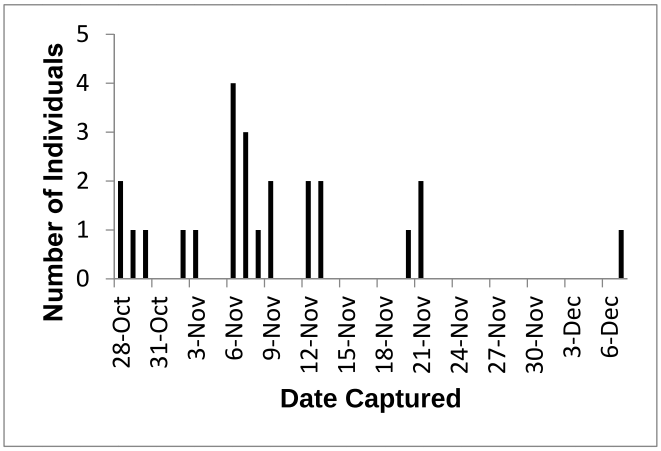

Figure 5. Saw-whet captures at Ozark Natural Science Center during November and December 2014 and October to December 2015.

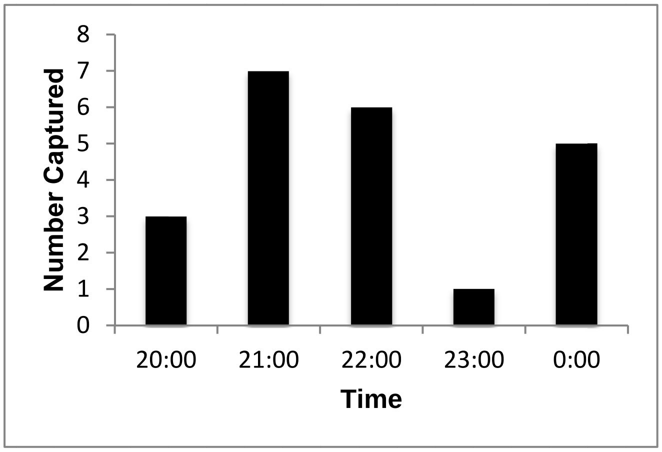

Figure 7. Saw-whets captured per hour at Ozark Natural Science Center during October and November 2015.

as a female in October 2013 at Stevens Point, Wisconsin and captured at ONSC in November 2015 (Fig. 8). This owl was underweight (80g) with a CWC of 144mm. The second recapture occurred on 21 November 2015 and was banded (0914-99385) on 30 September 2015 at Hawk Ridge Bird Observatory near Duluth (Saint Lewis County), Minnesota (Figure 8). The distance between the two research sites is 1186 km indicating the bird averaged at least 23 km/night. This ASY female weighed 91g and had a CWC of 145mm. We also had a local recapture during our 2015 season. A HY female was banded on 7 November 2015. She weighed 86g, which is slightly underweight. The bird was recaptured the following night, 8 November, and weighed 91g. She had dried blood on her beak and talons, indicating she had eaten between captures.

Vocalizations were heard on several occasions. On the first night of netting in 2014, one bird was responding to the audio lure when another gave the 2-note alarm call when it was flushed from a cedar tree. Another bird responded immediately when the audio lure was turned on on 6 December, but no birds were captured that night. During fall of 2015, at least 10 birds were detected vocally, with at least one occasion when 2 or maybe 3 birds were calling simultaneously. In most cases, birds appeared to vocalize after the whine call was played, often calling repeatedly each time the whine call was played.

Discussion

From this research, we conclude that the Northern Saw-whet Owls are, in fact, more common in Arkansas than previously thought, at least during fall migration in the northwestern part of the state. With only 12 previously confirmed records in Arkansas, averaging about one record every 4 years, we did not expect to capture any saw-whets. However, with 24 total captures and additional vocal detections over 2 fall seasons, it is reasonable to believe the species previously went undetected, probably due to their secretive nature (Rasmussen et al. 2008). Continuation of this project for several more years should determine their exact status in Arkansas.

All but one of the birds we captured were females, which is consistent with more males being captured further north (Brittain et al. 2009, Beckett and Proudfoot 2012). Brinker et al. (1997) suggested this is because males do not stray as far from prime breeding habitat, allowing for quicker reoccupation in spring when they are vying for precious cavities for nesting. Alternatively, the larger and heavier females may have dietary requirements that are met further south (Weir et al. 1980, Beckett and Proudfoot 2012). Such differential migration is not uncommon in birds and has been documented in the Boreal Owl (*Aegolius funereus*), a close relative of the saw-whet (Brinker et al. 1997).

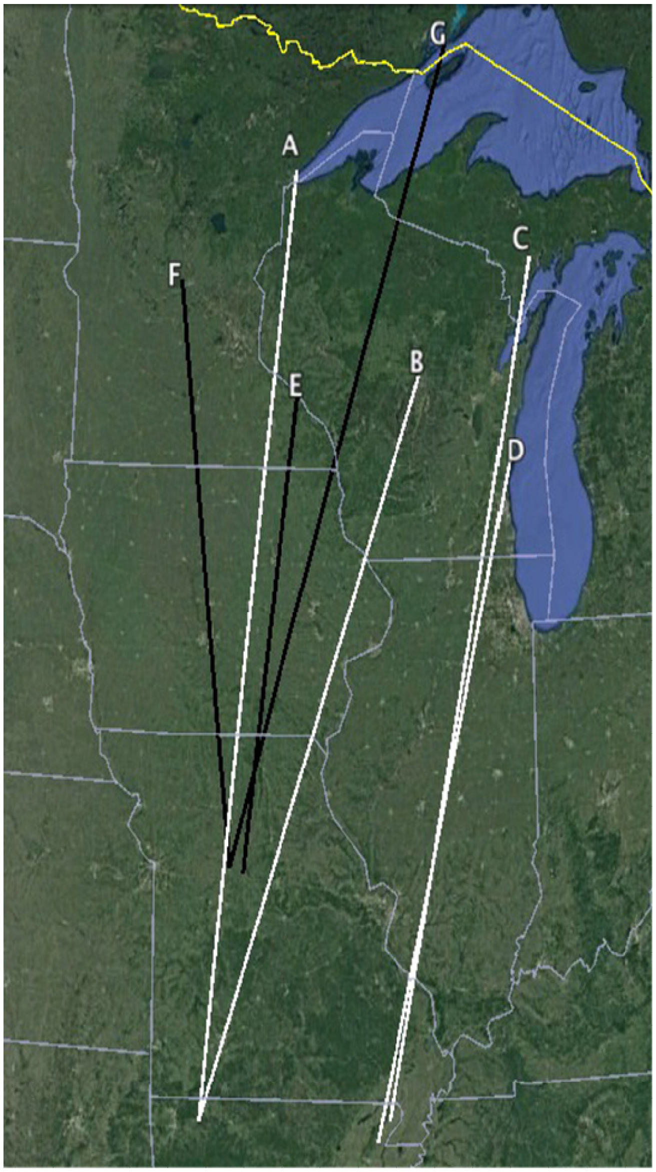

Figure 8. Banding recoveries from Arkansas (white) and from the Missouri River Bird Observatory (black) (D. Ripper, *unpubl. data*). Most birds appear to be coming from the western Great Lakes region. Key (banded, recovered): A (9/2015, 11/2015), B (10/2013, 11/2015), C (10/1990, 2/1992), D (11/1969, 12/1969), E (10/2015, 11/2015), F (10/2015, 11/2015), G (?/2013, 10/2014).

Based on only one full field season, we cannot attribute much to the equal distribution of age classes that we found. Brittain et al. (2009) found that the number of HY birds fluctuated annually from about 30% to 50% in southern Indiana. At northern locations, HY birds usually appear first in the fall, but our limited data suggest that they arrive at the same time as adults in northwestern Arkansas.

In our region, other banding efforts for saw-whets have been conducted only in Alabama and Missouri. Banding was conducted by R. Sargent from 2007-2013 in Clay (Jefferson County), Alabama with a total of 104 individuals captured (data from the USGS Bird Banding Laboratory, Patuxent, Maryland). Efforts at the Missouri River Bird Observatory in and around Marshall (Saline County), Missouri began in 2010 and continued through fall of 2015, with a total of 117 captures. Annual capture rates at that site ranged from 6.0-15.0 birds per 100 net-hours (D. Ripper, *unpubl. data*). Our capture rate for fall of 2015 is right in the middle of that range and catching 24 birds in fall is also about the average for the Missouri site. Thus, the fall migration in northwestern Arkansas is very comparable to that in central Missouri.

Captures in our 2015 season started in late October, peaked during the first few weeks of November, and decreased to no captures after the first week of December. This trend is also similar to that of Missouri (D. Ripper, *unpubl. data*) and slightly before that of northern Alabama, where captures continued into January (R. Sargent, *unpubl. data*). This difference in Alabama might be because those birds are following a different migratory pathway (see below). This peak in early November coincides exactly with the prediction from the model presented in Beckett and Proudfoot (2011) for a northern latitude of about 36 degrees. Our results agree with those authors that fall migration of saw-whet owls is a uniform front that moves southward as fall progresses.

Weather conditions also appear to play a role in successfully capturing saw-whets. The nights that we captured the most birds followed cold fronts from the north, suggesting that migrating birds were riding those fronts. Brittain et al. (2009) also caught more birds in southern Indiana following the passage of fronts and on nights with calm winds (see also Weir et al. 1980). Nights with full moons are typically unproductive (Speicher et al. 2011), because birds can see the mist nets or they may be wary of larger, predatory owls, such as Barred Owls (*Strix varia*), which were commonly heard calling at our field site. However, four captures were made in late October when the moon was an 85% full waning gibbous. This was probably due to leaves still being on the trees, and the forest near our nets being dark.

Based on the 4 foreign recoveries from Arkansas and 3 of 4 from Missouri, it would appear that the saw-whets migrating to our region are coming from the western Great Lakes region (Fig. 8). Four recoveries from Arkansas were two birds banded in Wisconsin, one from Minnesota, and another banded in the Upper Peninsula of Michigan. Three recoveries from Missouri include two birds banded in Minnesota, and one from southeast Ontario (Figure 8). (Another bird captured in Missouri came from Prince Albert, Saskatchewan, far to the northwest.) These data appear to establish a here-to-fore unknown migration route for saw-whets, flying south or southwest from the western Great Lakes to the Ozarks (see Confer et al. 2014). Birds in Alabama most likely are not coming from the western Great Lakes, but down the Appalachian Mountains, which might explain the longer banding season there.

Two of the recaptures occurred in the same fall the birds where banded, allowing us to calculate a minimum daily rate of 30 km/night (assuming that they do not fly during the day) in 1969 and 23 km/night for the 2015 bird. These compare favorably with the average of about 29 km/night reported by Brittain et al. (2009) in southern Indiana based on 9 birds, and many long-distance migrants reported in Wisconsin by Erdman et al. (1997). This is also consistent with the estimate that the migration front moves about 30 km/night (Beckett and Proudfoot 2011).

During the 2014 and 2015 field seasons, we were able to document several different vocalizations. One of the vocalizations played by the audio lure was the male's territorial *toot, toot, toot* call. We heard no response to this call because it is rarely heard outside breeding season and saw-whets do not breed in Arkansas. Another vocalization we played as an audio lure was an eerie, drawn out whine call that is heard most frequently in fall and could be a contact call used during migration to locate other individuals (Rasmussen et al. 2008). Most often a response to the whine call was heard, but we documented several other vocalizations as well. Another common call heard during field research was a quick *ksew* or chirping note. This was often elicited by flushing birds while checking nets. Both the *ksew* and squeak seemed to be given by agitated individuals. *Ksew* notes were also heard while listening from a distance, meaning they are probably given off in agitation towards other individuals as well. On one occasion, a two note, squeaking alarm call was heard from a flushed bird. On another occasion, two individuals were heard high up in a pine giving a series of soft chirping notes, seemingly talking back and forth to each other. The saw-whet owl is still understudied outside of the breeding season, making it difficult to understand the social context behind most of their vocalizations.

Based on the scattered historic records, it would appear saw-whets could be found throughout the state. There are also other large tracts of suitable cedar habitat in northwestern Arkansas. Thanks to publicity of our project, we were contacted by Becky Christenson, who had 2 images of a saw-whet from a trail camera that she had set up on her property, approximately 16 km south of Kingston (Madison County) on County Road 3655. Presumably the same bird, the first image was taken at night on 23 December 2014 and the second image was taken on 12 January 2015. Her property is about 32 km due south of our study site at the Ozark Natural Science Center. This is likely just one of several unknown and unreported individuals.

After early December, our capture rates dropped to zero and saw-whets seemed to vanish. We continued our banding operation into January and early February of 2015, but caught or heard no birds. The banding station in Missouri also typically shuts down after the first week of December as they do not catch any birds after that time (D. Ripper, *pers. comm.*). However, sporadic records in Arkansas from December to February suggest that some individuals may spend the winter here.

There are several possibilities why no birds are heard or captured after early December. First, they could be going further south, but there are no records in southern Arkansas and almost none in Louisiana. Second, they could be spending winter in the Ozarks, but they no longer respond to audio lures after late November, perhaps becoming net adverse. Third, they could be returning north in December, but that seems to oppose the logic behind migration. Or they could be doing something completely different, like wandering throughout winter, as found in Snowy Owls (*Bubo scandiacus*) (Norman Smith, *pers. comm.*).

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Infection with the Sand Flea *Tunga penetrans* (Tungiasis) in a Traveller Returning from Cameroon, Africa

D.J. Richardson* and A.M. Mangili

School of Biological Sciences, Quinnipiac University, 275 Mt. Carmel Avenue, Hamden, CT 06518

*Correspondence: Dennis.Richardson@quinnipiac.edu

Abstract

Tungiasis refers to human infection with adult fleas, *Tunga penetrans*. Although common throughout the tropics, tungiasis is rarely encountered by physicians in the United States such that it may be improperly diagnosed and inappropriately treated. We provide a case report of tungiasis in a traveler from Cameroon and a brief review of reported cases in the United States and Canada.

Introduction

Tungiasis refers to human infection with adults of the flea, *Tunga penetrans*. *Tunga penetrans* is the smallest known flea, attaining a maximum length of no more than 1 mm (Eisele et al. 2003). Common names applied to *T. penetrans* include chigoe flea, chigger flea, sand flea, bicho de pé, jigger, nigua, chica, pico, pique, and suthi (CDC 2013, Smith 2015). *Tunga penetrans* is unique in that the female flea actually penetrates and resides within the skin of its host. Although both male and female fleas take blood meals, only the female penetrates the host. After penetration, the female exhibits profound hypertrophy attaining a diameter of up to 1 cm. Eight to ten days after penetration, females begin laying eggs that are released from the host (Lefebvre et al. 2011). During the 4-6 weeks that the fleas reside in the host, hundreds of eggs may be released. Subsequently, the fleas die and are sloughed from the epidermis by skin repair mechanisms (Heukelbach 2005). After 3 to 4 days in the soil, eggs hatch and release larvae. The larvae feed on organic debris and pass through two instars before becoming pupae that are encased in cocoons normally covered in soil. The time from hatching until emergence of the adult stage is 3 to 4 weeks. The adult's main diet consists of blood from mammals where mated females burrow underneath the skin, leaving only their abdomens exposed to lay eggs (CDC 2013, Feldmeier et al. 2014). *Tunga penetrans* utilizes a wide variety of reservoir hosts including rats, dogs, cats, monkeys, goats, cattle, horses, and pigs (Heukelbach et al. 2001, Cestari et al. 2007, Feldmeier et al. 2014). The life cycle of *T. penetrans* is given in Fig. 1.

Although native to South and Central America, *T. penetrans* has become widely distributed throughout the tropics via trade routes, having become particularly abundant in sub-Saharan Africa. Although common throughout the tropics, tungiasis is rarely encountered by physicians in the United States such that it may be improperly diagnosed and inappropriately treated. Nearly all cases diagnosed in the United States resulted from international travel to countries in Africa and South and Central America. The only autochthonous reported human case in the U.S. was that of a man in New Orleans in 1929 who reportedly contracted the infection while sitting on infested sisal hemp imported from Mexico (Faust and Maxwell 1930), although Augustson (1942) reported *T. penetrans* from a Pacific Horned Owl (*Bubo virginianus pacificus*) at Oceanside in San Diego California. The purpose of this paper is to provide a case report of tungiasis in a traveler from Cameroon and to briefly review cases reported from the United States and Canada.

Case Report

During the summer of 2013, a 50 year-old male research biologist visited Bawa, Cameroon on a medical missions trip. The area comprises a tropical mountain forest with a rainy season extending from April through September. See Richardson et al. (2011) for a climatic and demographic description of the area. On 12 July, the subject noticed single small, black furuncular-like lesions on the little toe and bottom of the left foot with minor swelling and minor pain. On 13 July he returned to the United States of America. The lesions persisted with little change. On 17 July, a physician examined the subject. Patient presented furuncles on the left foot characterized by left foot paronychia of 5th digit and also an area on mid forefoot sole. Paronychia was characterized by discoloration and tenderness. The lesions were diagnosed as foreign objects with characteristic inflammation. The lesion

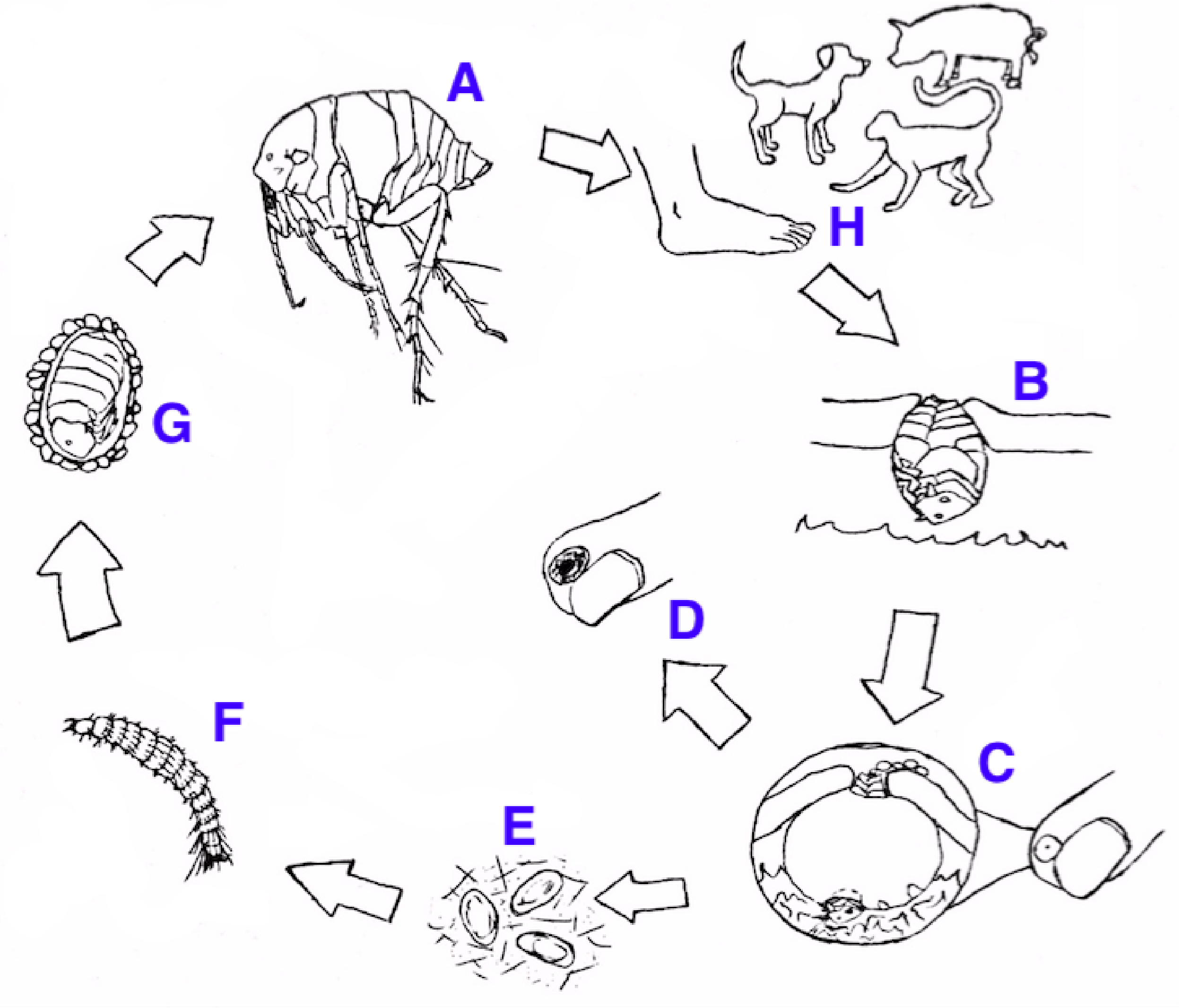

Figure 1. Life cycle of *Tunga penetrans*. After CDC (2013) with information from Cestari et al. (2007) and Feldmeier et al. (2014). **A.** The free-living adult female is a maximum of 1 mm long. Both adult male and female fleas take blood meals. **B.** The female penetrates the skin of the host, leaving the distal abdominal segments exposed so as to form a "cone" providing contact with the outer environment, through which it may breath, defecate, copulate and expel eggs. Immediately, hypertrophy of the abdomen begins and within a few days, the female attains a diameter of up to 1 cm and begins passing eggs to the outside environment. **C.** During the next 2-4 weeks the female may pass hundreds of eggs, which fall to the soil. **D.** After expulsion of eggs, involution of the lesion begins and the flea dies. Remains of the flea are sloughed off in the course of skin repair mechanisms. **E.** Eggs hatch in 1-6 days releasing larvae. **F.** The larvae feed on organic debris and pass through two instars over the next 5-7 days. **G.** Cocoons that are often covered with debris such as sand contain the puparium. Adults emerge from the cocoon after 9-15 days. **H.** Almost any domestic or wild mammal may serve as a reservoir for human infection.

on the little toe was probed with a hypodermic needle. Liberated clear fluid contained small black particles that were assumed to be parts of a foreign object. It was later determined that the "debris" were parts of the flea. Vital signs and hematological findings, including differential leukocyte counts, were not remarkable. The patient was prescribed a seven-day course of Keflex. The removal procedure was followed by an inflammatory response characterized by moderate pain and erythema. It is presumed that the erythromaceous swelling resulted from an inflammatory response to the dead flea and fluids. This was followed a month later by necrotic discoloration (Fig. 2).

On 18 July, 8 additional furuncular lesions appeared (Fig. 3).

From 18 July to 29 July, patient reported minor pain with periodic intense pruritus associated with the "new" lesions. On 23 July, patient lanced the initial lesion on the right little toe with a sterile hypodermic needle to relieve swelling, moderate-severe pain, and pruritus associated with the lesion. Limited cellulitis was also noted. A moderate amount of clear fluid was liberated. Within several hours, the pain, pruritus and cellulitis subsided.

Figure 2. Necrotic discoloration following attempted surgical removal. One month after procedure.

Figure 3. Early lesions associated with *Tunga penetrans*.

On 30th July, all pain associated with lesions subsided. On August 2nd the patient returned to the physician. Lesions had increased in size. Patient presented large pustular lesions with centrally located black dots under toes on right side and below right hallux nail (Fig. 4), also on the mid sole and left little toe. Based on the appearance of the lesions, diagnosis was made as furnucular myiasis associated with *Cordylobia anthropophagia*. Diagnosis was made based primarily on reference to Palmieri et al. (2013).

Figure 4. Flea below right hallux nail.

On 8 August dermal exfoliation of 4th toe of right foot was noted. On August 9, the flea began to detach from the lesion and was removed leaving an ulcer (Fig. 5). Substantial movement of the flea was observed indicating that the flea was still alive. The flea was fixed in 95% v/v ethanol and prepared for microscopic observation that facilitated the diagnosis of tungiasis. The removed flea is shown in Figs 6-9.

Figure 5. Flea, *Tunga penetrans*, detached from lesion on 4th toe of right foot on 9 August. Note dermal exfoliation and resultant ulcer.

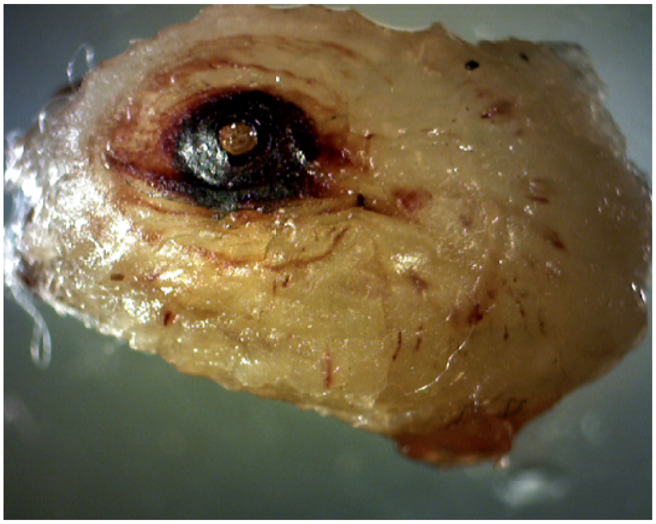

Figure 6. Posterior of flea, *Tunga penetrans*, removed from 4th toe of right foot.

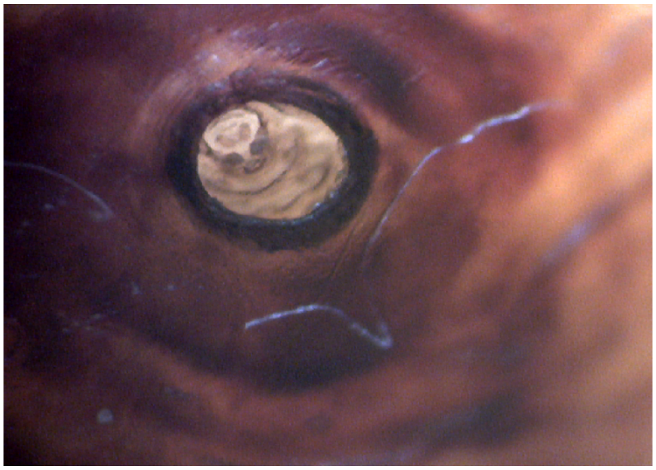

Figure 7. Close up of anal-genital opening of flea, *Tunga penetrans*, removed from 4th toe of right foot.

On the morning of 10 August, pruritus subsided. There was substantial dermal exfoliation around all remaining lesions. Pruritus resumed on lesion on the bottom of foot with moderate to severe pain and erythematous swelling (Fig. 10). Clear fluid exuded from the lesion and walking was difficult. After about an hour, pain and pruritus subsided. It is presumed that the flea had ruptured leading to an intense inflammatory response.

On 18 August, an additional flea became partially detached and was removed (Fig. 11). In total, only 2 fleas were removed. It is presumed that the remaining fleas died and were sloughed off by normal skin repair mechanisms. By early September, lesions were completely healed without sequela.

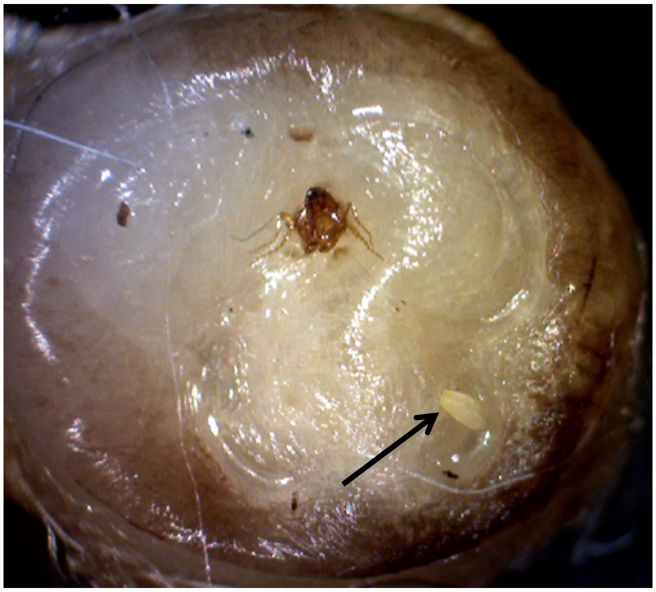

Figure 8. Anterior of flea, *Tunga penetrans* showing head. Note that the anterior portion of the flea is in the shape of a cloverleaf (Eisele et al. 2003). An egg is indicated by the arrow.

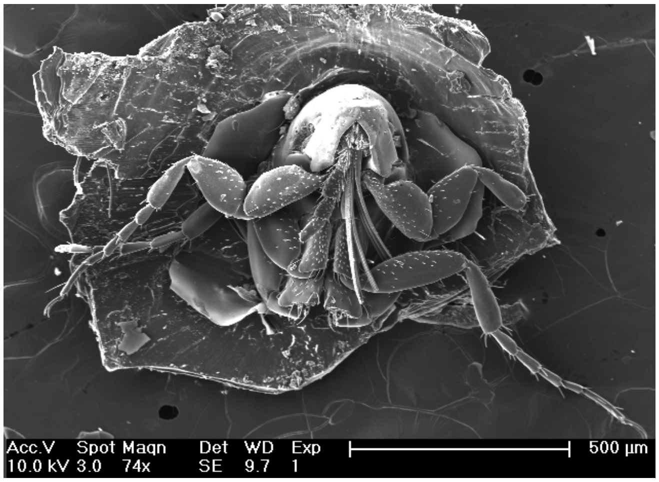

Figure 9. SEM of head of flea, *Tunga penetrans*, removed from 4th toe of right foot.

Remarks and Discussion

This case report constitutes a typical course of infection with *T. penetrans*. Although common throughout much of the developing world (Feldmeier et al. 2014), tungiasis is rarely encountered in the United States and Canada and nearly exclusively in travelers returning from endemic areas. A confounding diagnostic factor is that lesions may not appear for several days (up to 30), following penetration of adult fleas (Palicelli et al. 2016). The paucity of reports of tungiasis may result in misdiagnosis and improper

Figure 10. Swelling around flea, *Tunga penetrans*, and lesion on plantar region of right foot following "rupture" of flea on 10 August.

Figure 11. Removal of flea, *Tunga penetrans*, from underneath right hallux nail on 18 August.

treatment; therefore, it is important to educate clinicians on the presentation and course of infection of this flea. Feldmeier et al. (2014) provided an excellent brief characterization of the pathogenesis of tungiasis as follows: "The inflammatory response around burrowed viable, dead, or decaying sand fleas is the basis for the clinical and pathological manifestations. Acute inflammation—characterized by erythema, edema, pain and itching—is caused by the growth of a biologically active foreign body within the epidermis, exerting pressure on the surrounding tissue." Eisele et al. (2003) provided an excellent comprehensive overview of the course of infection with *T. penetrans*.

Tungiasis may easily be mistaken for a foreign object in early stages of infection or furuncular myiasis in later stages, as with the present case. Tungiasis is restricted to the feet 99% of the time (Thielecke et al. 2013), particularly in areas of soft skin, such as the space between toes, under toenails, and along the medial border of the feet (Cestari et al. 2007). Although rare, tungiasis should be considered a potential threat to travelers, particularly those visiting South America and Africa, as serious complications may result from secondary infections that may lead to cellulitis, abscess formation, lymphangitis, sepsis, tissue necrosis, gangrene, erysipelas, and deep mycosis (Binford and Connor 1976, Fein et al. 2001, Cestari et al. 2007). Therefore, early treatment with topical and/or parenteral broad-spectrum antibiotics is recommended (Spielman et al. 1986). Untreated tungiasis is also a risk factor for tetanus in unvaccinated individuals (Cestari et al. 2007). Additionally, inflammation may be related to the presence of endosymbiotic *Wolbachia* bacteria (Feldmeier et al. 2014), which is known to be present in *T. penetrans* (Heukelback et al. 2004).

Sanusi et al. (1989) reviewed 14 cases of tungiasis diagnosed in the United States that appear in the scientific literature. Table 1 provides an overview of the 14 cases summarized by Sanusi et al. (1989) along with 12 additional cases from the United States and one from Canada.

Wearing socks and closed-toed shoes, especially in sandy areas (Lefebvre et al. 2011), may help reduce the risk of infection although Thieleckek et al (2013) found that wearing shoes failed to reduce the incidence of infection. Application of a repellant based on coconut oil (Zanzarin) twice a day was reported to reduce infection rate by almost 100%. Treatment is extraction of fleas by enucleation with a sterile vaccionostylet, needle, or curette (Feldmeier et al. 2009, Lefebvre et al. 2011). Care should be taken not to rupture the flea, or leave any part of the flea in the lesion as this may lead to an intense inflammatory reaction (Heukelback et al. 2001, Lefebvre et al. 2011), as described in the present case study.

Table 1. Synopsis of cases of tungiasis reported in the literature from the United States and Canada, including the cases reported by Sanusi et al. 1989 and subsequently reported cases.

Reference	Reported Location	Age, Sex	Number and Location of Lesions	History of Exposure	Treatment
Faust and Maxwell 1930	New Orleans, Louisiana	Adult, M	Many around pubic and inguinal areas, lower right abdomen	Sat on sisal hemp from Mexico	Phenolized ointment
Reiss 1966	New York City, New York	Adult, M	Several on both feet	Traveled to Lambarene, Gabon, Africa	Flea removal, applying antibiotic ointment
Goldman 1976	Cincinnati, Ohio	5, F	4 on plantar, 3 on back, 1 under breast, 1 on wrist, and 1 under nail	Traveled to Africa	Debrided, irrigated with saline, bacitracin and polymyxin B sulfate ointments
Brothers and Heckmann 1979	Provo, Utah	21, M	1 on toe	Travelled to Rio de Janeiro, Brazil	Curettage, antibiotic
Taubman and Spielman 1979; Spielman et al. 1986	New York	44, F	4 on 2nd and 5th toes of left foot	Traveled to Lima, Peru	Curettage
Bell et al. 1979	Memphis, Tennessee	63, M	1 on lateral side of left heel, 1 on plantar surface, 1 under right 5th toenail	Travelled to Manaus near Ponta Negro, Brazil	Treated with cephalexin, excised fleas
Zalar and Walther 1980	New York	29, F	Several on both 1st toes and 5th toe of right foot	Traveled to Ethiopia, Tanzania, and Kenya	Curettage, bacitracin ointment
Poppiti et al. 1983	Miami, Florida	25, M	Several on lateral sides of both feet	Travelled to Brazil	Flea removal
Armin et al. 1985	Maywood Illinois	70, M	1 under toenail of 2nd toe right foot	Travelled to Africa	Flea removal, topical antibiotic bacitracin
Wentzell et al. 1986	Hanover, New Hampshire	17, M	2 on periungual area of 1st and 5th toes on right foot	Travelled to Brazil	Curettage, dissected bluntly, antibiotic ointment
Milgraum and Headington 1988	Ann Harbor, Michigan	30, M	1 on 2nd toe	Traveled to Canaima National Park, Venezuela	Not Given
Sanusi et al. 1989	Shreveport, Louisiana	24, M	2 on 3rd and 2nd toes of right foot	Traveled to Zaire, Africa	Flea removal
Dalton and Haldane 1990	Halifax, Nova Scotia, Canada	43, M	1 on sole of right foot	Travelled to Venezuela	Debrided with sterile needle
Burke et al. 1991	Greenville, North Carolna	18, M	Distal lateral portion of right great toe	Travelled to Brazil	Excised with scalpel blade and base curetted, topical polymycin B & bacitracin ointment
Lowry et al. 1996	Fort Bragg, North Carolina	Adult, F	Feet and toes	Travelled to Brazil	Curettage
Mashek et al. 1997	Buffalo, New York	33, F	Many on plantar and periungual areas on both feet	Immigrated from Somalia and lived in Kenya	Debrided, curettage, dicloxacillin, bacitracin ointment
Lucchina et al. 1997	Massachusetts	30, F	Several on 1st and 5th toes of right foot	Traveled to Brazil	Curettage, electrodesic-cation
Darmstadt and Francis 2000	Seattle, Washington	1, F	5th toe of right foot	Adopted from Paraguay	Nail clipped back, unroofed and debrided

Table 1 Cont.

Fein et al. 2001	Cincinnati, Ohio	4, F and 6, M	Many on soles and toes of both feet	Adopted from Liberia, Africa	Flea removal, antibiotics
Brane et al. 2005	Cincinnati, Ohio	29, F	1 on 1st toe of left foot	Traveled to Kenya	Flea removal, antibiotic ointment
Van Buskirk et al. 2006	Detroit, Michigan	55, F	Right heel	Traveled to Tanzania	Excisional biopsy
Hager et al. 2008	Texas	24, F	1 on left first toe	Traveled to Tanzania, Africa	Curettage, and light hyfrecation
Appiah et al. 2013	Baltimore	14, M	20 on right foot, 9 on left foot, soles and sides	Traveled to Guyana, South America	Topical 10% albendazole ointment, curettage

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New Distributional Records of the Ohio Shrimp, *Macrobrachium ohione* Smith (Decapoda: Palaemonidae) in Arkansas

H.W. Robison[1], L. Lewis[2], C. Cox[3], G. Spooner[4], R. Adams[4], and C.T. McAllister[5*]

[1]*Department of Biology, Southern Arkansas University, Magnolia, AR 71754-9354*
[2]*US Fish and Wildlife Service, Arkansas Field Office, 110 South Amity Rd., Suite 300, Conway, AR 72032*
[3]*Arkansas Game and Fish Commission, Northeast Regional Office, 600 East Lawson Road, Jonesboro, AR 72404*
[4]*Department of Biology, University of Central Arkansas, Conway, AR 72035*
[5]*Science and Mathematics Division, Eastern Oklahoma State College, Idabel, OK 74745*

*Correspondence: cmcallister@se.edu

Running Title: New Records of *Macrobrachium ohione* in Arkansas

Abstract

The Ohio shrimp (*Macrobrachium ohione*) is a migratory (amphidromous) river shrimp that occurs in some Arkansas rivers. It is known from the Upper Missouri River from its mouth downstream to the Gulf of Mexico, but shrimp abundance has declined, particularly upstream of Louisiana. Ohio Shrimp has also been collected in the lower reach of the Missouri River not far from the confluence of the Mississippi River in St. Louis County. Dams and alterations in channel flow are hypothesized to have impacted upriver migrations of shrimp. Current range, abundance, and life history of Ohio shrimp is relatively unknown in the Mississippi River basin in reaches distant from sea water. Here, we report recent collections of Ohio shrimp in Arkansas rivers that were notably greater than 800 km from the Gulf of Mexico.

Introduction

Only 2 species of freshwater shrimps of the family Palaemonidae (Order Decapoda) inhabit Arkansas, the Mississippi grass shrimp, *Paleomonetes kadiakensis* Rathbun, and the Ohio shrimp, *Macrobrachium ohione* Smith (Bouchard and Robison 1980). Robison and McAllister (2011) reviewed the distribution, life history aspects, and conservation status of both shrimps in Arkansas and provided locality records for each.

Macrobrachium ohione is a large freshwater shrimp (up to 110 mm total length) characterized by having the first pairs of legs chelate, the second pair larger than the first, the carpus of the second leg not subdivided, a hepatic spine present, the upper edge of the rostrum curved with 9–13 teeth and a toothless dagger-like tip, with the second pereopods enlarged and greatly elongated. It is not easily mistaken for any other crustacean in Arkansas.

The Ohio shrimp is the most abundant and widely distributed river shrimp in the United States with specimens collected from Alabama, Arkansas, Florida, Georgia, Illinois, Indiana, Louisiana, Mississippi, Missouri, North Carolina, Ohio, Oklahoma, South Carolina, Texas, and Virginia as well as coastal streams of northeastern Mexico (Bowles and Knight 2000).

In Arkansas, *M. ohione* has been reportedly taken from the Mississippi, Arkansas, and Red rivers (Bouchard and Robison 1980); however Robison and McAllister (2011) were able to only document its occurrence in the Mississippi River from only 6 collections in 2 counties (Chicot and Phillips) in Arkansas from 1914–2011. Those 6 collections totaled 42 specimens of *M. ohione* known for the state previous to the present study.

Here we document new distributional localities for *M. ohione* in Arkansas as well as information on aspects of its biology from recent collections of this large shrimp.

Methods

During October 2010, April–May 2012, May–July 2015, and October 2015–November 2015, Ohio shrimp were collected in the lower Arkansas, White, St. Francis, and Mississippi rivers. Methods of collecting included use of baited wire shrimp traps, boat electrofishing, seining, aquatic dip nets, and boat trawling using a Missouri Trawl (Herzog et al. 2005). Individuals were preserved in 70% ethanol or isopropanol. Total length (TL) was measured on select shrimp to assess age class using previous literature values (Truesdale and Mermilliod 1979). Some voucher specimens were deposited at the University of

Central Arkansas (UCA) for further study while others are housed at Henderson State University (HSU). The number of specimens (Appendix) is the total number found at a site.

Results and Discussion

Size classes

At sites outside the Mississippi River, 94 individuals included 50 young-of-year (<40 mm TL), 44 age-1 (40–90 mm TL), and zero age–2 (>90 mm TL) individuals. Four age–1 females caught in the White River during late June and early July of 2015 had eggs visible between the swimmerets.

Sex ratios and measurements

Of 48 individual Ohio shrimps collected in 2015 with wire mesh traps and boat electrofishing in the lower Arkansas River, 22 were males with a mean total length of 43.3 ± 5.8 (32.3–55.9) mm and 26 were females measuring 44.9 ± 7.5 (31.5–64.3) mm. In the Mississippi River, 43 *M. ohione* were taken: 33 were males (42.3 ± 6.9, 32.3–61.8 mm) and 10 were females (41.0 ± 10.8, 27.5–56.6 mm).

Reproduction

Four ovigerous females (77.1–87.0 mm TL) were collected from the White River on 25 June and 7 July 2015. These were the largest and only ovigerous *M. ohione* collected during 2015.

Collection habitat

Specimens captured during 2015 were predominantly collected in shoreline and nearshore habitats in association with rip-rap along revetted banks and wing dikes where flow ranged from 0.06 to 0.25 m/s.

Barko and Hrabik (2004) reported *M. ohione* preferred open side channels and main channel borders of the Mississippi River in Missouri. Conaway and Hrabik (1997) found Ohio shrimp preferred low velocity waters; however, open side channels have flow during normal river elevations (Barko and Herzog 2003). This shrimp receives reproductive cues from spring floods and uses flooded terrestrial habitat for reproduction (Hobbs 2001). Robison and McAllister (2011) collected *M. ohione* in the Mississippi River over sandy substrates in 0.6–0.9 m of water devoid of vegetation. No appreciable current was detected in these areas 6–9 m offshore adjacent to sand bars.

Table 1. Physicochemical parameters collected in 2012 with *Macrobrachium ohione* in Arkansas River at Norrell Sill (Post Canal).

Date	21 April	5 May	1 June
Water temp (°C)	21.1	25.9	27.3
Time (hrs)	2000	2158	2136
Conductivity (ms/cm)	0.25	0.33	0.56
Salinity	0.13	0.15	0.26
D.O. (mg/l)	9.28	6.71	6.45
pH	8.0	7.7	8.4

Water quality

Along with collections of *M. ohione* from the Arkansas River in Arkansas County, water quality data was also collected at the same time (Table 1). While these data are not intended to be indicative of parameter limits of *M. ohione*, they are suggestive of the general type of water quality found in the Arkansas River at that time.

Parasites

Two *M. ohione* collected in the Mississippi River were parasitized by bopyrid isopods belonging to the genus *Probopyrus*. These ectoparasites were found underneath the carapace and attached to the gills of *M. ohione*. Infection of adult shrimps is common in *M. ohione* from the Atchafalaya and Mississippi Rivers, Louisiana (Conner and Bauer 2010); however, this is the first report, to our knowledge, from Arkansas shrimps.

New collections

This study reports 135 additional specimens of *M. ohione* from 11 new localities (Fig. 1) in Arkansas including 4 new county records in Arkansas, Desha, Lee, and Mississippi counties (Appendix). The L'Anguille, White and St. Francis River collections were previously undocumented locations, expanding the known range of Ohio shrimp. Additionally, these are the first specimens documented from the Arkansas River since, presumably, 1853. Previous research (Robison and McAllister 2011) noted the importance of main stem Mississippi River habitat to Ohio shrimp, but our data suggest tributaries should also be considered in the conservation of this species.

With the addition of these collections and now a

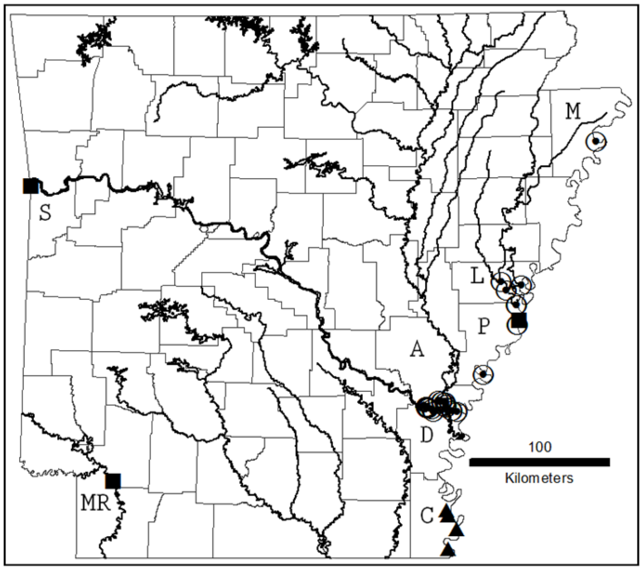

Figure 1. Arkansas county records for M. *ohione*. Square (USNM records 1853-1905); triangle (1974-75); circle with dot (New records, 2010-2015). County abbreviations: A (Arkansas); C (Chicot); D (Desha); L (Lee); M (Mississippi), MR (Miller); P (Phillips); S (Sebastian).

total of 177 total specimens for the state, it still appears that *M. ohione* is a relatively rare shrimp in Arkansas waters. The senior author (HWR) has pursued this shrimp for over 45 yrs in the state and, to date, only specimens from 36 collections of *M. ohione* have been documented. Additional research is currently underway to continue the search for other populations of *M. ohione* in Arkansas. Further collecting is encouraged to continue to follow this most interesting crustacean.

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Appendix. New locations of 135 specimens of *M. ohione* from 30 collections in Arkansas (locality [latitude/longitude when available, as estimated from collection locations], date of collection, collector, and number of specimens).

ARKANSAS CO. (57 specimens, 17 collections)

1. Arkansas River at Norrell Dam Sill (Post Canal)

(34.01915°N 91.19542°W). 21 April 2012. C. Cox, L. Pearson, C. Naus, and M. Loudermilk. 1.

2. Arkansas River at Norrell Dam Sill (Post Canal) (34.01915°N 91.19542°W). 5 May 2012. C. Cox, L. Pearson, C. Naus, and M. Loudermilk. 1.

3. White River downstream of Benzal Bridge along western side of river associated with large wood and rip-rap (33.97881°N, 91.15969°W). 21 May 2012. L. Lewis and C. Cox. 1.

4. Arkansas River at Norrell Dam Sill (Post Canal) (34.01858°N, 91.19373°W). 1 Jun. 2012. C. Cox and L. Pearson. 1.

5. Lower Arkansas River downstream of Wilbur D. Mills Dam (33.98334°N, 91.30832°W). 12 Jul. 2012. L. Lewis, C. Cox, and R. Adams. 1.

6. White River at Wild Goose Area (34.02366°N, 91.22218°W). 13 Jul. 2012. L. Lewis, C. Cox, and R. Adams. 1.

7. Lower Arkansas River downstream of Wilbur D. Mills Dam (33.9775°N, 91.3003°W). 24 Oct. 2013. L. Lewis and G. Grimes. 1.

8. Lower Arkansas River <1 km downstream of Wilbur D. Mills Dam (33.98264°N, 91.31197°W). 11 Jun. 2015. L. Lewis. 8.

9. White River at Benzal Railroad Bridge (33.9988°N, 91.16002°W). 25 Jun. 2015. L. Lewis. 2.

10. Lower Arkansas River <1 km downstream of Wilbur D. Mills Dam (33.980198°N, 91.306988°W). 25 Jun. 2015. L. Lewis. 21.

11. Lower Arkansas River at Wilbur D. Mills Park Boat Launch (33.9789°N, 91.307°W). 7 Jul. 2015. L. Lewis, J. Throneberry, and G. Spooner. 11.

12. White River at Benzal Railroad Bridge (33.9988°N, 91.16°W). 7 Jul. 2015. L. Lewis, J. Throneberry, and G. Spooner. 2.

13. White River <2.3 km downstream of Benzal Railroad Bridge (33.9789°N, 91.1605°W). 7 Jul. 2015. L. Lewis, J. Throneberry, and G. Spooner. 1.

14. Lower Arkansas River downstream of Morgan Point Bendway on left ascending bank (33.972105°N, 91.270966°W). 6 Aug. 2015. G. Spooner, L. Lewis, R. Adams, and J. Gill. 1.

15. Lower Arkansas River at Notrebes Park Boat Launch (33.986595°N, 91.309573°W). 6 Aug. 2015. G. Spooner, L. Lewis, R. Adams, and J. Gill. 1.

16. Lower Arkansas River downstream of Wilbur D. Mills Park Boat Launch (33.977619°N, 91.304909°W). 6 Aug. 2015. G. Spooner, L. Lewis, R. Adams, and J. Gill. 2.

17. Lower Arkansas River <1 km downstream of Wilbur D. Mills Dam (33.9795°N, 91.3077°W). 24 Sept. 2015. L. Lewis and R. Adams. 1.

DESHA CO. (11 specimens, 5 collections)

1. Mississippi River downstream of White River confluence (33.95096°N, 91.07603°W). 11 Jun. 2015. L. Lewis. 2.

2. White River <3 km downstream of Norrell Lock and Dam 1 (Post Canal) (34.0126°N, 91.1667°W). 7 Jul. 2015. L. Lewis, J. Throneberry, and G. Spooner. 1.

3. Lower Arkansas River <6.5 km downstream of Wilbur D. Mills Dam (33.9548°N, 91.2597°W). 24 Sept. 2015. L. Lewis and R. Adams. 5.

4. Lower Arkansas River 8 km downstream of Wilbur D. Mills Dam (33.9588°N, 91.2493°W). 24 Sept. 2015. L. Lewis and R. Adams. 1.

5. White River right ascending bank, outside bend and at dike (33.9592°N, 91.1165°W). 23 Oct. 2015. L. Lewis, R. Adams, and G. Spooner. 2.

LEE CO. (4 specimens, 3 collections)

1. Mississippi River upstream 1.2 km of Battle Axe Launch/Ramp, left ascending bank, side channel behind island within dike field. (34.7495°N, 90.5524°W). 8 Oct. 2010. L. Lewis, L. Holt, R. Campbell. 2.

2. L'Anguille River just upstream of confluence with St. Francis River (34.7229°N, 90.6704°W). 28 May 2015. L. Lewis and R. Adams. 1.

3. L’Anguille River/Ditch 60 upstream of confluence with St. Francis River. (34.7778°N, 90.7122°W). 15 Oct. 2015. L. Lewis. 1.

MISSISSIPPI CO. (23 specimens, 1 collection)

1. Mississippi River at Sans Souci Landing S of Osceola (35.655427°N, 89.925932°W). 16 Oct. 2015. H.W. Robison, D.A. Neely, U. Thomas, C.T. McAllister, R.A. Hrabik, D.P. Herzog, and D.E. Ostendorf. 23.

PHILLIPS CO. (40 specimens, 4 collections)

1. Mississippi River downstream from mouth of St. Francis River confluence, left ascending bank (34.62324°N, 90.59344°W). 28 May 2015. L. Lewis and R. Adams. 2.

2. Mississippi River downstream of confluence of St. Francis River left ascending bank (34.62322°N, 90.59345°W). 14 Aug. 2015. L. Lewis. 2.

3. Mississippi River at Sunflower Dikes and islands (34.183246°N, 90.867604°W). 19 Nov. 2015. L. Lewis and R. Adams. 35.

4. Mississippi River at Walden Landing, Helena (34.4984°N, 90.5916°W). 19 Nov. 2015. L. Lewis and R. Adams. 1.

Polyethylene Oxide Nanofiber Production by Electrospinning

H.E. Schneider[1], J.G. Steuber[2], W. Du[3], M. Mortazavi[3], and D.W. Bullock[1]

[1]*Department of Electrical Engineering, Arkansas Tech University, Russellville, AR 72801*
[2]*Department of Mechanical Engineering, Arkansas Tech University, Russellville, AR 72801*
[3]*Department of Chemistry & Physics, University of Arkansas at Pine Bluff, Pine Bluff, AR 71601*

Correspondence: dbullock@atu.edu

Running title: Electrospun Polyethlyene Oxide Nanofibers

Abstract

Electrospinning is an inexpensive technique that is used to produce nanofibers for a variety of applications. In electrospinning, a polymer solution is dispensed from a hypodermic-like syringe where an intense electric field attracts the solution to a collector while drawing the polymer into a very thin fiber. The diameter of the fiber can be controlled by tuning the process parameters such as the applied electric field, solution flow rate, distance between syringe tip and collector, and the collector geometry. In this paper we describe results from electrospinning poly(ethylene oxide) (PEO), a likely candidate for applications involving scaffolding for tissue engineering. The PEO nanofibers were fabricated from different polymer solution concentrations ranging from 14% - 22% (by weight). Each sample was then imaged using a scanning electron microscope. The morphology of the fibers produced from varying solution concentrations is discussed.

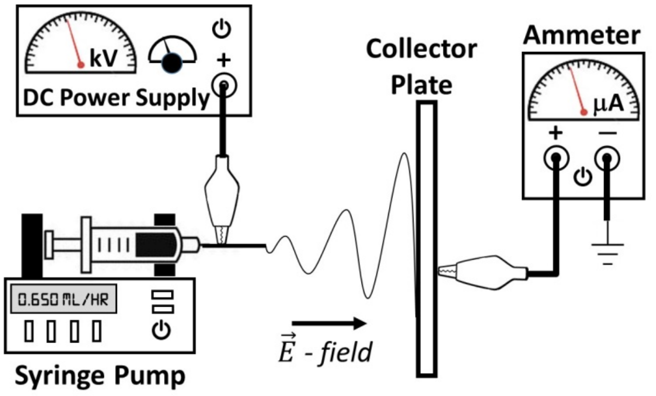

Figure 1. An illustration an electrospinning apparatus consisting of a solution dispensing system, high voltage power supply and collector plate.

Introduction

Electrospinning is an inexpensive technique that can be used to produce nanofibers from a variety of different material systems. With the nanofibers' high surface area to volume ratio, they have shown great promise in applications ranging from filtration systems (Kosmider and Scott 2002), catalysis (Demir et al. 2004), energy harvesting (Chang et al. 2012), and biomedical engineering (Fang et al. 2008). One exciting example is the potential to use electrospun nanofibers as scaffolding for tissue engineering applications. In order for these nanofibers to be used as scaffolding they must meet several requirements; namely, they must be porous to promote the growth of living cell tissue, exhibit adequate structural integrity, and they should be biocompatible so that it is not toxic to living cells (Ma 2004). Poly(ethylene oxide) (PEO) is a biocompatible, porous material that is an excellent candidate for enzymes as chemical catalysts (Xie and Hsieh 2003) and scaffolding for tissue engineering applications (Subramanian et al. 2012).

Electrospinning is a technique that can be used to produce fibers ranging in diameter from tens of nanometers to several microns (Beachley and Wen 2009). Although electrospinning systems can vary depending on the application, all systems contain the same fundamental components. Figure 1 is an illustration of an electrospinning apparatus consisting of three integral parts: a solution dispensing system, high voltage power supply, and a grounded collector. The solution dispensing part of the electrospinning apparatus is composed of a syringe filled with the polymer solution of interest. Connected to the syringe is a metallic hypodermic needle, often referred to as a spinneret. The spinneret serves two purposes: one is to provide a surface from which the solution will form a drop that will eventually be pulled out into a fiber, and secondly the spinneret provides an electrical connection which is used to transfer charge to the surface of the solution. For most applications the spinneret has a simple uniaxial geometry, however it is possible to use coaxial or even triaxial spinnerets to produce nanofibers that have core-sheath structures (Sun et al. 2003). The syringe-spinneret assembly is loaded into a syringe pumping system that allows for precise control of the flow of the solution out of the spinneret. Connected to the spinneret is a high voltage DC power supply. The power supply is used to impart charge to the solution and orient the electric field which is required for the electrospinning process. The final component of the system is a collector plate. The collector plate is used to collect the randomly oriented nanofiber samples as well as providing an electrical connection to ground. In Figure 1, a simple flat plate collector is shown, however it is possible to use more complicated collector geometries in order to produce aligned nanofibers (Li et al. 2003). One of the most common examples is a rotating drum geometry that consists of a metal cylinder that is rotating about its axis (Katta et al. 2004). By translating the drum or the spinneret back and forth while the drum is rotating it is possible to form nanofibers that exhibit a high degree of alignment. Connected in series to the collector plate is a digital ammeter that is used to measure the collector current. Under standard electrospinning conditions, the collector current typically measures in the tens of micro-amps, however the magnitude of the current is not as useful as the stability of the measurement. When the current measurement is relatively stable this indicates that the apparatus is producing fibers at a steady rate.

In this paper, our objective is to study fiber formation and morphology as it relates to the PEO solution concentration.

Materials and Methods

Electrospun poly(ethylene oxide) (PEO) fibers were produced by first dissolving PEO powder (having a molecular weight of 100,000 g/mol) purchased from Sigma-Aldrich in distilled water. Aqueous solutions ranging in concentration from 1% to 22% (by weight) were prepared. Each solution was then stirred overnight at room temperature using a magnetic stirring plate to ensure a homogenous solution. The solution being tested was then poured into a 10 mL syringe that was attached to a 21 gauge (diameter of 0.8 mm) stainless steel needle via a standard 1/8" polyvinyllidene fluoride (PVDF) tubing. The syringe was then loaded into a model NE-1000 Multi-Phaser^{TM} programmable syringe pump. The pumping rate was programmed to be between 0.55 – 0.65 ml/hr. This pumping speed was such that when a small droplet would form at the tip of the syringe and wiped away, it was quickly replaced with a new droplet as a result of the pumping speed. An Acopian High Voltage power supply was used to provide positive DC power, ranging from 2-20 kV, to the syringe. The high voltage power supply was current limited to around 2mA. To accurately measure the syringe voltage, a Vitrek 4700 precision high voltage meter (accurate to within 0.35% of voltage reading) was incorporated into the experimental setup by attaching a metal alligator style clip directly to the syringe and then connecting the clip to the voltage meter via high voltage wire. Randomly oriented fibers were collected using an electrically grounded stainless steel flat collector plate (145 mm × 230 mm × 1 mm). For each experiment, the collector plate was wrapped with a single layer of aluminum foil in order to easily collect and transport samples for microscopy as well as ensuring an electrical connection to ground.

In order to study the effect of PEO solution concentration on fiber formation, desired solutions were loaded into the syringe and placed into the syringe pump and an appropriate pumping speed was set corresponding to 0.55 – 0.65 mL/hr. The collector plate was then placed 10-12 cm from the end of the syringe. To observe the initiation of jet formation, a Hovercam Solo 8 high magnification, 4k resolution, long working-distance CCD based document camera was placed over the tip of the syringe. Care was taken to ensure that the distance the camera was located relative to the syringe was great enough to not disturb the electric field generated at the syringe tip. Next, high voltage DC power was supplied to the syringe and slowly increased until a stable jet was observed. After stability was established by monitoring the collector current, the high voltage power supply was turned off and a fresh layer of aluminum foil was placed on the collector plate. The power was then turned on and samples were collected for 5 minutes. Each solution was tested under ambient conditions. In order to ensure similar conditions the room temperature and humidity levels were recorded for each sample and the ambient temperatures were within ± 2 ºC and humidity levels were within ± 5% of each process run.

Each sample was stored in a climate controlled environment for at least 24 hours to ensure adequate drying of the fibers. The samples were then imaged using a Phenom Scanning Electron Microscope (SEM) at the University of Arkansas – Pine Bluff Advanced Physics Lab facility. Multiple images were taken for each sample. The samples were imaged without adding a metallic sputter coating.

Results

Characteristic SEM images for three successively higher solution concentrations (14%, 18%, and 22% respectively) are shown in Figures 2a, 2b and 2c. Each of these images measures 45μm × 45μm and are cropped from debris free areas. Fibers were spun for concentrations ranging from 14% to 22%. Attempts were made to produce fibers from concentrations below 14% however, fibers formation was not observed for these samples. Also, attempts were made to spin fibers from concentrations above 22% however, above this concentration the solution was too viscous to stir to ensure a homogenous solution. The 14% concentration image in Figure 2a shows the onset of fiber formation. The image also reveals several small spherical polymer beads. Figures 2b and 2c show significant fiber formation with the density of fibers being larger in 2b and smaller in 2c. Additionally the fibers shown in figure 2c are larger in diameter when compared to those shown in Figures 2a and 2b.

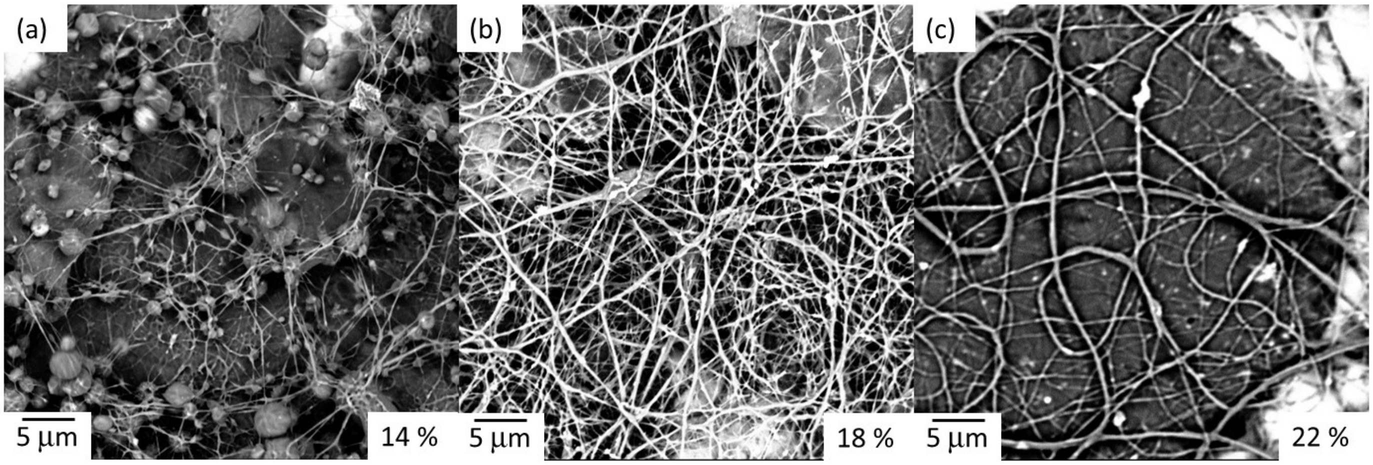

Figure 2. SEM images (45μm × 45 μm) of electrospun fibers produced from three different PEO solution concentrations (a) 14%, (b) 18%, and (c) 22%. For each concentration, the fibers were produced using an 18 kV tip potential, 15 cm tip-collector separation, and a 0.65 mL/hr solution pumping speed.

Discussion

The morphology of nanofibers formed by electrospinning is a result of several process parameters. These parameters can be classified into two categories. In the first category the parameters are a result of the hardware setup. These include the syringe pumping speed, spinneret type (uniaxial, coaxial, etc.), applied voltage, distance between the spinneret and collector, and the collector type and geometry. The second category of process parameters are those due to the solution chemistry. These parameters include solvent type, solute molecular weight, solution temperature, and solution concentration. Each of the process parameters (both hardware and chemistry) can have an effect on the resultant morphology of the nanofibers.

During the electrospinning process, a small droplet of solution is subjected to an intense electrostatic force resulting from the applied electric field. The magnitude of the electrostatic force is directly proportional to the electric field and the total charge on the droplet, via Coulomb's Law ($F = qE$, where F is the magnitude of the electrostatic force, q is the total charge on the drop and E is the intensity of the electric field). The electric field intensity is determined by the ratio of the applied voltage to the syringe tip-collector separation distance ($E = V/d$, where E is the electric field intensity, V is the voltage applied to the syringe, and d is the tip-collector separation). When the electrostatic forces are strong enough the droplet becomes elongated and can form what is known as a Taylor cone. The Taylor cone is the result of hydrodynamic forces (resulting from the solution pumping rate), electrostatic forces (resulting from the applied electric field), and viscoelastic forces (resulting from the surface tension and viscosity of the solution). If the electrostatic forces are strong enough to overcome the surface tension of the Taylor cone the solution will develop a jet whereby either microscopic droplets or strings of solution are ejected from the cone. If droplets are formed, this is known as electrospraying, whereas if strings are ejected it is termed electrospinning. To produce nanofibers the jet must eject string like structures. When this happens the string experiences an acceleration towards the collector plate. As the string traverses the gap between the Taylor cone and collector plate it is elongated and this elongation causes the string to experience axial thinning, so that by the time the jet has reached the collector, the size can be on the order of magnitude of several tens-hundreds of nanometers. The thinning process is not only an artifact of the stretching of the string as it reaches towards the collector, but it is also a result of the evaporation of the solvent due to the increasing surface area of the string structure.

One of the most important process parameters at play during the electrospinning process is the solution concentration. The solution concentration effects the viscosity of the polymer, as the solution concentration increases the solution becomes more viscous. In the limit of extremely high viscosities (resulting from a very high solute concentration) the electrostatic force on the solution is not strong enough to initiate a jet from the tip of the syringe. In this limit the applied electric field needed to initiate a jet would be on the same order of magnitude as the electric breakdown voltage of the polymer. If the viscosity is reduced (but maintained relatively high) by decreasing the solution concentration, it has been shown that large helix shaped fibers will form (Yang et al. 2004). Further reduction in the solution viscosity will result in smooth, continuous fibers (Eda and Shivkumar 2007, Fong et al. 1999, Lee et al. 2003). In general it has been shown that within this process window of intermediate concentration that larger diameter fibers form with higher concentrations and the diameter tends to decrease with decreasing concentration. As the concentration is decreased further there is a mixture of fibers and beads formed. As the concentration becomes lower the surface tension of the solution becomes the dominant factor and fiber formation no longer occurs (Deitzel et al. 2001). At these low concentrations the viscosity is low relative to the solution's surface tension leading to the formation of spheres as a result of minimizing the Gibb's surface free energy.

Conclusions

In conclusion, we present results of the electrospinning process that produces PEO nanofibers. In order for nanofibers to form a critical concentration must be reached. Below this concentration beads are formed. Further increasing the concentration results in a mixture of beads and fibers. As the concentration becomes higher uniform, continuous fibers are formed. In general, in this fiber formation regime, as the concentration increases so does the diameter of the fibers.

Acknowledgements

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Biomass (yard waste) Suspensions as Alternative Daily Cover Material for Landfills

R. Sharma[1*], K. Arnoult[1], K. Hart[1], G. Phillips[1], S. Knight[2], and M. Grappe[2]

[1]*College of Agriculture and Technology, Arkansas State University, Jonesboro, AR*
[2]*Saline County Regional Solid Waste Management District, Benton, AR*

*Correspondence:rsharma@astate.edu

Running title: Biomass Suspension as Alternative Daily Cover Material for Landfills

Abstract

Biomass makes up approximately 16% of the landfills (this number can vary significantly depending upon the geographical location and time of the year). A majority of the biomass disposed in landfills is comprised of yard waste including grass and leaf clippings. This is becoming a problem as most landfills are running out of space and it is expensive to build new landfills. Twenty-four states have prohibited the disposal of yard waste in landfills with more states likely to follow suit. To conserve landfill space it is important to identify processes and methods for effective utilization and disposal of yard waste. It has been shown in this research that conformal coating of a biomass suspension can be utilized as an alternative daily cover (ADC) for the landfills. The biomass is ground into fine particles ($d \leq 2$ *mm*) and suspended in a surfactant solution. This approach can reduce the cost of daily operations for the landfill and provide a solution to the problem of yard waste disposal.

Introduction

Sustainable waste management is critical to the future of the planet. This is an issue which has an impact on every person. Still, it is surprising that we do not even have an accurate estimate of municipal solid waste (MSW) generation in the country. As per EPA fact sheet on municipal solid waste, Americans generated about 254 million tons of trash in 2013 (EPA 2015). Almost 52.8% of the MSW was discarded in landfills. Remaining MSW was recovered, recycled, composted or combusted for energy recovery (waste-to-energy or WTE). Approximately 16% of the MSW is composed of biomass (yard trimmings, wood etc.). Almost 60% of this biomass is recycled (20.6 million tons of yard trimmings composted or wood waste mulched in 2013). Remaining biomass ends up in landfills. According to some other reports the amount of MSW generated as well as going to landfills was significantly higher. (Shin 2014, Arsova et al. 2008). Irrespective of the discrepancies in the reported data, we know that there is a large tonnage of MSW going in the landfills and biomass makes up a significant percentage of this MSW.

Landfills typically use a daily cover of approximately 15 to 23 cm of compacted soil, which acts as a barrier for odors, blowing trash, fires and keep birds and insects away. The drawbacks of using soil as daily cover have been well known. It reduces the fill capacity of landfills. According to an estimate the volume taken up by soil in a typical land fill is about 20-25% of its capacity (Solan et al. 2010). Decreasing availability of new landfill sites along with space in existing landfill is of concern to solid waste management community worldwide. Using soil as a daily cover increases the operational expenses due to labor and fossil fuels costs for excavating and moving the soil. This has resulted in a search for alternatives for daily cover. EPA conducted a study in 1993 where they investigated several alternative daily cover (ADC) materials. Several materials such as foams, spray-on, geosynthetics and a variety of other materials which are disposed in landfills were identified which can replace soil as daily cover (Pohland and Graven 1993).

Application of yard waste as an alternative daily cover material has tremendous potential. Yard waste is not only widely available, waste management companies have to spend money and efforts in disposing yard waste. A significant amount of yard waste (average composition by weight is about 50 percent grass, 25 percent brush, and 25 percent leaves) is disposed in landfills. It has become an operational challenge as the existing landfills are filling up and building new landfills is capital intensive task. The disposal of yard trimmings in landfills is not a good choice due to its high organic matter content (López et al. 2010). In addition to the capacity issues, there are regulatory challenges. Twenty-four states representing about 39 percent of the population of the United States have banned the disposal of yard waste in landfills and it is expected that several other states would also do the same (EPA 2015). Even though the amount of yard waste sent to landfills has decreased by 50% in past two decades (Miller 2013), there is need to reduce this amount even more. It is important to develop new methods and processes for effective management of waste biomass that would prolong the life of landfills.

One such approach could be to use yard waste to create ADC that could replace the daily cover of soil. It has been shown that the use of organic waste material as ADC is a better strategy in terms of greenhouse gas emission reduction as compared to that of composting (Kong et al. 2009). This was true even when there was no collection system is in place for landfill gasses. A life cycle analysis study compared the use of yard waste for ADC versus the composting (Haaren et al. 2010). It was shown that the using yard waste for composting is far more expensive than its use as ADC. It was also determined that the use of yard waste as ADC in place of soil is environmentally preferable. Another study also concluded that using vegetative mulch as daily and intermediate landfill cover is an option that is more environmentally friendly as compared to composting or combustion (Haddad 2011).

The objective of this study was to develop a method to prepare a durable protective biomass layer using yard waste and evaluate its performance for its potential application as an alternative daily cover for landfills. Biomass suspensions were prepared using yard trimmings particulate material and surfactants or surface-active reagents. Several different types of surfactants were tested for the stability of biomass suspensions. The biomass suspension was used to create a conformal coat that can be utilized as an ADC for the landfills.

Methods

Sample preparation

The biomass (yard waste) was collected from several residential neighborhoods in Jonesboro, Arkansas. Yard waste consisted of but not limited to pine needles, pine bark, pine cones, dried leaves, leaf clippings, dried grass and small limbs. Since the components of the yard waste were fairly large and varied in size, the first step in the sample preparation was size reduction of the yard waste collected. This was a two-step process. First step was to reduce the biomass to ¼ its size (small enough to fit into the grinder). We used a basic leaf shredder for this step. This allowed it to be further processed in the laboratory grinder. This biomass was ground using a laboratory mill (Thomas Wiley model 4) with a 2 mm sieve. The particle size of the reduced biomass was 2 mm or less. ($d \leq 2$ *mm*).

Biomass suspension and layer

A nonionic (Preference®, Winfield) and a cationic (Benzalkonium Chloride, Alfa aesar) surfactants were used to prepare the biomass suspensions. The active ingredients of Preference® consisted of Nonylphenol polyethylene glycol ether (55-65 % w/w), Isopropyl alcohol (10% w/w), and Poly(ethylene) oxide (<2% w/w). Benzylkonium chloride was a 50% w/w aqueous solution. Surfactants are known to have amphipathic structure. They have a hydrophilic as well as a hydrophobic component and can be used to reduce interfacial tension. They can adsorb on the surface of the biomass particles and impart a hydrophilic or hydrophobic characteristic to the surface depending upon the orientation of the surfactant molecule. The hydrophobic component of the surfactant can help keep the biomass particles apart and stabilize the suspension, whereas the hydrophilic group can reduce the interfacial tension and assist in formation of a cohesive layer. Stability of the suspension would be required during its application on landfills. It would be important to identify a surfactant that will have functionality for this task and is cost effective. Both of the surfactants chosen had very low toxicity and are used in several foods, pharmaceutical, and agricultural applications. It was important that these surfactants were environmentally safe chemicals. These surfactants are not very sensitive to the hardness of water that would be an important consideration if this process is adapted for the landfills.

A 0.125, 0.25, 0.5, 1, and 1.25% v/v concentration solutions of nonionic and cationic surfactants were prepared. A 1% solid loading solution was prepared to test the stability of the biomass suspension with both surfactants. A magnetic stirrer was used to stir the solution for 5 minutes. Settling time was recorded after the stirring was stopped.

A 25% solid loading slurry of biomass in a cationic surfactant solution was prepared to create a biomass layer. The slurry was spread on a test bed. The 30cm x 30cm (actual size: 1ft x 1ft) test bed was custom built and for these experiments. A fan was directed at the test bed to simulate the wind at a land fill (wind speed 0.5 m/s).

Results and Discussion

Figure 1 shows the settling of biomass particles in a non-ionic surfactant solution. Settling time for biomass particles was highest in the control suspension (no surfactant). The settling time decreased with increase in surfactant concentration up to 0.5% in the suspension. This was followed by an increase in settling time up to 1.25% surfactant concentration (M =322.04, SD = 28.04). This indicates that the non-ionic surfactant had an adverse effect on the stability of biomass suspension. Since non-ionic surfactants do not have a surface charge on their hydrophilic groups they would not have a strong affinity towards the negatively charged biomass surfaces. They would still weakly adsorb on the particle surfaces reducing the interfacial tension. This will increase the rate of immersional wetting. This reduction in interfacial tension also increases the cohesion of biomass particles resulting in formation of agglomerates. The larger mass of the agglomerates would contribute to the faster settling of biomass particles in non-ionic surfactant solution. It has been shown that the hydrophobic component (chain) of the surfactant may form nonelectrical steric barrier to aggregation in aqueous medium at high concentrations (Rosen 1989). The presence of these barriers may increase the stability of the suspension. However, this may happen only when there is a closed-packed vertical monolayer of surfactant is adsorbed on the surface. The monolayer of the non-ionic surfactant was not realized until the surfactant concentration used in these experiments (1.25% surfactant solution). This could be the reason the suspension with nonionic surfactant was less stable than the control. It has been shown that the concentration of the surfactant has a strong correlation with it orientation on the substrate such an increase in the amount of surfactant being used and resulting interfacial behaviors (Shubin 1994). This monolayer of surfactant could possibly have been achieved at a higher surfactant concentration. However would be cost prohibitive for large-scale operations.

Figure 2 shows the settling of biomass particles in a cationic surfactant solution. The settling time for biomass particles increased with increase in surfactant concentration up to 0.125% in the suspension. This was followed by a decrease in settling time (M =358.62, SD = 38.14). Another set of experiments was conducted between 0 and 0.125% concentration to determine if any lower concentration of surfactant can be used. Settling times were measured at 0.0125, 0.0250, 0.050, and 0.075% concentration. The settling time was highest at 0.05% concentration (429 s), which was slightly higher than 0.125% concentration (421 s). However, the noteworthy part of this test was reduction in surfactant concentration by 40% for almost similar stability. This suggests that the cationic surfactants can increase the stability of biomass suspension. Cationic surfactants have a positively charged surface-active polar group along with a hydrophobic tail. As a result of which they have attractive electrostatic interaction towards negatively charged biomass surfaces and preferentially adsorb on them. Since they adsorb with the polar group oriented towards the surfaces, the hydrophobic chains are oriented towards the aqueous phase imparting hydrophobicity to the surface. These hydrophobic chains deter the approach of particles to each other creating a steric barrier to coalescence. This keeps the particles apart preventing aggregation and slowing down the settling rate.

The next phase of this project was to generate a

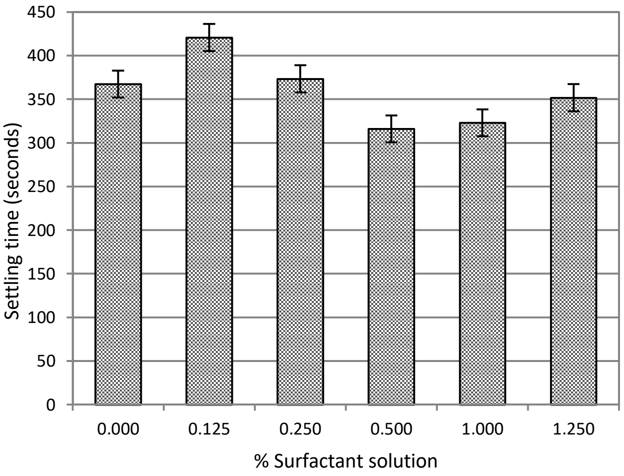

Figure 1. Settling of biomass particles in a non-ionic surfactant.

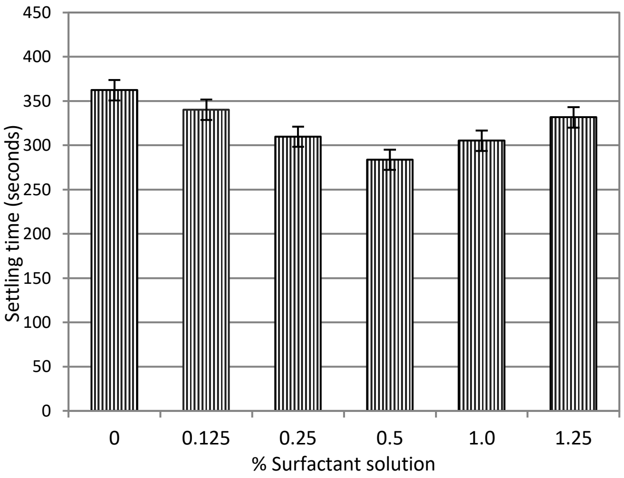

Figure 2. Settling of biomass particles in a cationic surfactant.

biomass layer using the prepared biomass suspension. A 0.05% cationic surfactant solution was used in this synthesis, which was previously determined as optimum concentration for stable biomass suspension. The biomass suspension was spread on a test bed and allowed to dry overnight. Figure 3 shows the testbed immediately after the slurry was spread and after it dried up. It was found that the biomass layer was quite sturdy and can possibly serve as effective protective cover over landfills. The surfactant reduced the interfacial tension between biomass particles allowing them to adhere together and resulting in a robust layer. It was also separately determined that this layer had hydrophobic properties as well. This was due to the hydrophobic portion of the surfactant molecules that were adsorbed on the particle surface. It did not disintegrate and held up well under the rain in an outdoor test.

A typical landfill has a footprint of approximately 111m^2 (Duffy 2005). Based on the amount of biomass used to generate a 2.54 cm thick layer in this study, it would take approximately 600 kg of biomass to cover the surface of a typical landfill. There are 1900 active landfills in this country (Zilmich 2015). If each of the landfill is covered with a 2.54 cm thick layer of biomass every day, it would require 416,100 metric tons of biomass per year. The total waste biomass generated each year is approximately 34 million tons (EPA 2015) which is significantly higher than what would be required for this approach.

Conclusion

This work demonstrated that waste biomass can be used to create sturdy and impervious layers. These biomass layers can be used as Alternative Daily Cover for landfills. It was found that a cationic surfactant provided with most stable biomass suspension. A 0.05% solution of this cationic surfactant was used to prepare biomass slurry which resulted in a robust layer. This can be a sustainable approach for utilizing waste biomass and generating daily cover for landfill operations.

Acknowledgements

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Figure 3. Biomass layer immediately and after overnight drying.

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Vegetation Diversity in Natural and Restored Forested Wetland Sites in Southeast Arkansas

C.J. Sheldon[1]*, R.L. Ficklin[1], K.P. Fawley[2], M.W. Fawley[2], M. Bataineh[1], A.S. Nelson[3] and S. Wilson[1]

[1]*School of Forestry and Natural Resources, University of Arkansas at Monticello, Monticello, AR 71655*
[2]*School of Mathematical and Natural Sciences, University of Arkansas at Monticello, Monticello, AR 71655*
[3]*College of Natural Resources, University of Idaho, Moscow, ID, 83844*

* Correspondence: cjsheldo@gmail.com

Running Title: Vegetation Diversity in Southeast Arkansas

Abstract

The loss of forested wetlands in the Lower Mississippi River Alluvial Valley in Arkansas has altered regional vegetation communities. Multiple restoration projects have been established in this region to restore wetlands and the services they provide. In order to return these functions to the environment, microtopographic features were constructed in 2001 at Bob White Memorial Wetlands Research and Teaching Station (Bob White). Vegetation diversity was examined at Cut-Off Creek Wildlife Management Area (Cutoff), a naturally forested wetland, and Bob White, an area formally converted to cropland that is now undergoing forest wetland restoration. Vegetation diversity is one way to determine if restoration efforts are effectively restoring ecosystem structure and functions to natural wetland conditions. Vegetation diversity and composition were examined across three topographical features: hummocks/ridges, swales, and flats. Vegetation diversity was examined in the spring, summer, and fall. Indices were used for determining composition similarities between Bob White and Cutoff. Bob White had a species richness of 33 and Cutoff's species richness was 47. Beta diversity between the two sites was 76 species, this value is high and suggests there is low similarity between the two sites. Sorensen-Dice Similarity Index value was calculated as 0.05, where on a scale of zero to one a low value indicates low similarity in composition. The low similarity between the two sites suggests that vegetation composition at Bob White has not been fully restored to conditions comparable to a natural setting. An explanation for this is the presence of *Baccharis halimifolia* (Eastern baccharis). *B. halimifolia* inhibits other species from colonizing. Another factor for the difference between the vegetation at Bob White and Cutoff is that Cutoff is an older forest. Hydrophyte communities in a forested wetland take 50 years after restoration begins for them to resemble a natural forested wetland. The results from this study provide mixed evidence that restoration at Bob White is succeeding; there is a high percentage of wetlands species, while vegetation lacks similarity. This study improves our understanding of the influence that anthropogenic changes have on wetland functions as agricultural lands are restored to their previous land cover. Ecosystem functions should continue to be monitored to determine time frames as these functions are restored to Bob White.

Introduction

Wetlands provide important environmental services to human and biological communities, such as flood attenuation, wetland-dependent wildlife habitat, water quality enhancement, sediment filtration, and pollution control through denitrification, wood products, and food production (Walbridge 1993, Gilliam 1994, Kleiss 1996, Mitsch and Gosselink 2000, Zedler 2003). In 1972 the Clean Water Act Section 404 was created to mitigate wetland loss (Hough and Robertson 2009), but this Act was largely unsuccessful. An estimated 25,212 hectare of wetlands were lost in the US between 2004 and 2009 (Dahl 2011). Wetland loss has decreased in recent years due to not only the Clean Water Act Section 404 but also successful education programs and fewer economic incentives available to drain wetlands (EPA 2011).

The physical properties of a soil determine its hydraulic character (Mitsch and Gosslink 2000). Depositional events in the Lower Mississippi Alluvial Valley (LMAV) are variable over time and result in differential microtopography and hydrological gradients. The Lower Mississippi River, its tributaries, and the landscape within these watersheds have undergone immense change in the past (Dahl and Johnson 1991), resulting in the loss of hydrologic characteristics found in natural wetlands (Mitsch and Gosselink 1993). Since the 1970s, the most extensive losses of wetlands have occurred in Arkansas, Mississippi, and Louisiana (Dahl and Johnson 1991, Kress et al. 1996). The change in land cover type from wetland to agriculture likely change the capacity of the land to lessen flood events (Hopkinson and Day 1980a, Hopkinson and Day 1980b), and improve downstream water quality (Hupp and Morris 1990, Hupp and Bazemore 1993).

Mature forested wetlands are known to exhibit varied microtopography due to erosion and sedimentation processes (Barry et al. 1996). Microtopography refers to any surface roughness in a forest stand or wetland area, usually at most ± one m of average elevation. Microtopographic lows hold water seasonally and have been suggested to be beneficial for maintaining hydric soil properties and hydrophytes during restoration (Bruland and Richardson 2005, Moser et al. 2009, Simmons et al. 2011). Microtopographic manipulations (Swales, Flats, and Hummocks) benefit a wetland's hydrologic regime (Tweedy and Evans 2001). Restoration with roughened microtopography ± 0.5 m was found to retain surface water more frequently throughout a year compared to a planar restoration site of similar age in coastal North Carolina (Tweedy and Evans 2001). Soil survey hydrologic classifications, poorly drained, somewhat poorly drained, and somewhat excessively drained can be predictors of the duration water is ponded on a soil.

Swale and hummock microtopography reestablishment during wetland restoration is expected to provide hydrological and edaphic benefits on otherwise planar sites. In less than a year saturated soils tend to develop characteristic redox potentials as well as denitrification processes (Megonigal et al. 1993). Following these processes prolonged anoxic conditions, slow soil microorganism activity, and promote the accumulation of soil organic matter (SOM), a key soil response to wetlands restoration (Bruland and Richardson 2006; Ballantine and Schneider 2009). SOM refers to any undecayed animal and plant matter as well as other humic substances, mainly composed of four elements: C (52-58%), O (34-39%), H (3.3%-4.8%), and N (3.7%-4.1%) (Sparks 2002). No differences in soil total carbon was found though total nitrogen was greater in the swale features five years after swale and hummock establishment in east Texas. (Simmons et al. 2011). It was also noted that hydrophytes colonized an initially bare site and swales held surface water as expected (Simmons et al. 2011).

Topographic modifications were evaluated for hydrologic, edaphic, and vegetative responses at a three year old wetland restoration site in coastal North Carolina (Bruland and Richardson 2005). Restored features included, hummocks rising one meter above average elevation, swales, and unaltered flats. Soil bulk density and soil organic matter did not differ among recreated swales, hummocks, and associated flats. Soil nitrogen, nitrate-nitrite-ammonium, significantly differed among the features. The authors suggest that microtopography heterogeneity provides heterogeneous aerobic and anaerobic zones within a wetland, benefiting nitrogen transformation and retention during restoration. Greater plant species richness and diversity has been found at intermediate flat areas (Simmons et al. 2011, Bruland and Richardson 2005). This is attributed to intermediate duration hydroperiod, whereas swales and hummocks experience moisture extremes.

The Wetland Reserve Program (WRP) developed by USDA Natural Resources Conservation Service (NRCS) was created to provide incentives for private land owners to conserve their property. These incentives have been the subject of public attention for their lack of effectiveness in conserving land. Specific research has focused on the assessment of the effectiveness of riparian buffers and wetland restoration methods (Gilliam 1994, Hill 1996, Hughes et al. 2005). Conservation incentives have been provided for the establishment of riparian buffers and wetlands in agricultural watersheds totaling 51,757 hectares in the LMAV (Faulkner et al. 2011). The titles of these conservation programs are varied: Riparian Forest Buffer, Wetland Wildlife Habitat Improvement, and Wetland Reserve Enhancement. The objective of these programs is to return marginally productive, poorly drained farmlands and pasture to forested wetlands. It has been suggested that ecological restoration strategies must address the challenge of structural complexities that vary greatly by ecoregion and the criticism over the lack of standard restoration monitoring practices (Suding 2011). Limited progress of wetland restoration toward reference features is due to failure to establish hydrophytes and planted hardwood trees at desired locations (Stanturf et al. 2001, Patterson and Adams 2003). In wetland restoration, progress toward reference conditions can refer to an abundance of hydrophytes, as well as appropriate water levels, and soil organic matter accumulation (Ballantine and Schneider 2009).

Evaluating wetland function is difficult because there is no standard to use for comparison when studying a specific function. Therefore, numerous studies have used reference wetlands to represent optimal habitat conditions (Brinson 1993, Brinson and Rheinhardt 1996, Wilson and Mitsch 1996, Ashworth 1997, Brown and Smith 1998, Stolt et al. 2000). Studying vegetation composition is one of the most commons metrics used to compare restored wetlands to reference wetlands. Studying vegetation alone is a poor measure of a wetland's function but is a quick and effective method for studying the biogeochemical condition of a wetland and is commonly used as a measure of success (Breaux and Serefiddin 1999). There are many advantages to using vegetation as a biological indicator: they are present in most wetlands, relatively easy to identify, sampling methods are well established, and their low mobility creates a direct link between onsite environmental conditions and plant community characteristics (Cronk and Fennessy 2001). Balcombe et al. (2005) found that species composition indicate wetland quality. Atkinson et al. (2005) found that there are very few studies that examined vegetation of wetlands more than ten years after construction. The long-term development of wetlands is poorly understood (Zedler 2000).

It has been accepted that changes in the vegetation diversity are associated with the different stages of succession (Hill and Jones 1978, Sykes et al. 1989, Gilliam et al. 1995). It is expected that more mature sites have a higher plant species richness than restored sites, because the vegetation on the mature sites has been undisturbed for a longer time than restored sites. Hydrophytic vegetation generally returns to wetlands three to five years after restoration begins (Brown 1999).

Materials and Methods

Site Description

Two study sites were used in this study. Their relation to each other is shown in Figure 1. The two sites are 32.2 kilometers apart. One area, Cutoff is a natural forested wetland, and Bob White is a former agricultural land undergoing wetland restoration. Cutoff is located in Drew County in southeast Arkansas. The 3,488 hectare wildlife management area consists mainly of bottomland hardwood forest. The majority of the property was acquired in a purchase in 1955 through the Wildlife Restoration Program Grant Fund. Before the purchase, Cutoff was high-graded for timber, only the highest quality of trees were harvested for timber resulting in relatively poor quality residual stands. The average forest age ranges from 50-100 years. The area is located within the Bayou Bartholomew Ecobasin, which is located within the LMAV ecoregion. Elevations range from 38 - 46 meters above mean sea level. The majority of hydrology in Cutoff is influenced by two drainage points: one just north of the management area, and the Cut-off Creek-Bayou Bartholomew drainage. The Perry Clay soil series (very-fine, smectitic, thermic Chromic epiaquerts) is the primary soil mapped for the site. This hydric soil is very poorly drained, with zero to three percent slopes and composed of Arkansas River sediments (Cloutier and Finger 1967). Cutoff had a gradient in microtopography features: swales (low laying areas), hummocks/ridges (mounds), and flats (the intermediate between the other two features).

Bob White comprises 146 hectares and is located in the LMAV in Chicot County, Arkansas. Elevations range from 32-34 meters above sea level. Similar to Cutoff, the soils on the Bob White tract are mapped as Perry Clay series. Bob White was bottomland hardwood forest (BLHF), until the 1960's when it was converted into row crop production. Once Bob White was enrolled in the WRP in 2001 Swale excavation and hardwood planting of bald cypress (*Taxodium distichum*), water oak (*Quercus nigra*), overcup oak (*Quercus lyrata*), green ash (*Fraxinus pennsylvanica*), and willow oak (*Quercus phellos*) occurred. The swale excavations created low laying features called swales, the excavated material was used to create mounds or hummocks, high laying areas, and lastly the areas not manipulated created flats, the intermediate between the two other features. The region where the microtopographic manipulations were done and where the plots for this study were placed has an average planted tree survival zero per ha (Smith 2006).

Study Design

Five plots were randomly placed within each of three microtopographic features at each study site. The gradient of microtopographic features included swales (low laying areas), hummocks/ridges (mounds), and flats (the intermediate between the other two features). The vegetation plots were one m^2 plots. These plots were surveyed May 6th – May 11th, August 28th - August 31st, and October 22nd – October 29th in 2015. Plants were identified using Schummer et al. (2011). Species richness was determined for each plot. A plant was considered in the plot if it was rooted within the plot. Vines were counted if they were present in the plot. Plants that could not be identified were collected from the surrounding area and identified in a lab. Some of the species were only found in the plots, so pictures

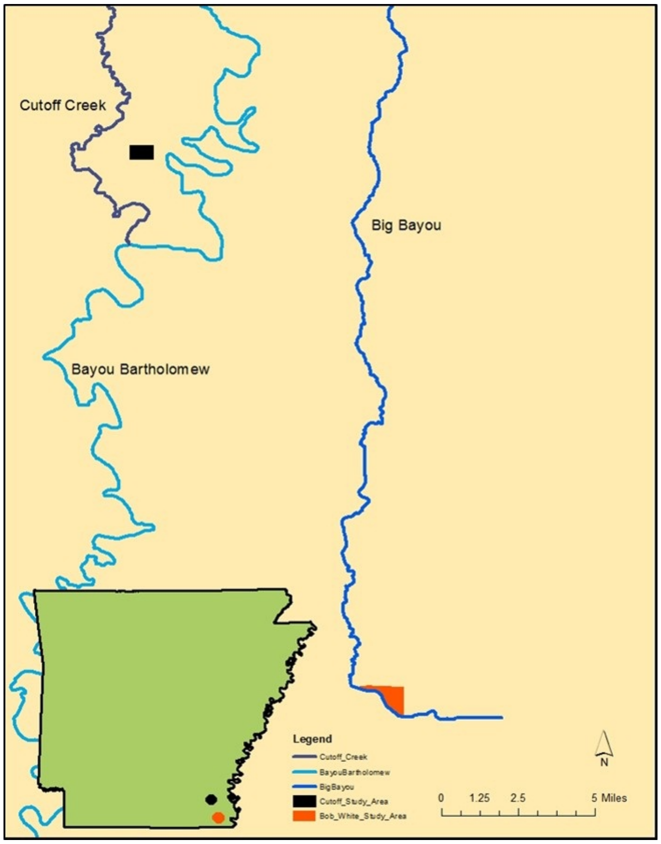


Figure 1. The location of the study sites coordinates for the vegetation plots at both study sites.

were taken and used for identification. Beta diversity was defined as the spatial variation in species composition and abundance between sampling units (Whittaker 1972). Sorensen-Dice Similarity Index and Jaccard/Tanimoto Coefficient were calculated across the two sites and within the sites and topographic features. The index ranges from zero to one where zero is no similarity between sites and one is exact similarity in species composition (Murguía and Villaseňor 2003, Tan et al. 2005).

The wetland indicator status of the plants that were identified to species were determined for the Atlantic and Gulf Coastal Plain region using the National Wetland Plant List by Lichvar et al. (2014). The wetland indicator status categories are defined as: Obligate (OBL)- almost always occurring under natural wetland conditions, Facultative Wetland (FACW)- usually occurring in wetlands but occasionally found in non-wetlands, Facultative (FAC)- equally likely to occur in wetlands and non-wetlands, Facultative Upland (FACU)- usually occurs in non-wetlands but occasionally found in wetlands, and Upland (UPL)- occurs in wetlands in another region, but almost always under natural conditions in non-wetlands in the region specified (Lichvar et al. 2012).

Beta diversity was calculated as

$$\beta = (A - C) + (B - C)$$

Where A is the total number of species found at a site, B is the total number of species found at another site, and C is the total number of species shared between the sites. Sorensen-Dice Similarity Index was calculated as

$$S = (2 * C)/(A + B)$$

Where A, B, and C are the same as above. Jaccard/Tanimoto Coefficient was calculated as

$$J = C/(A + B - C)$$

Where A, B, and C are the same as above.

Linear mixed-effects regression models were used to assess species richness. All models were fit using PROC MIXED in SAS 9.4 for Windows (SAS Institute, Cary, NC, U.S.A.). Species richness, models included study site, topographic feature, and topographic feature within study site. The random statements used included study site, topographic feature within study site, and survey period within topographic feature. All parameters were evaluated at an alpha level of 0.05.

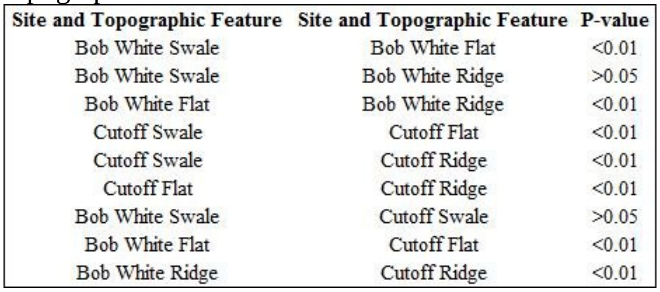
Results

Thirty-three different plant species were identified at Bob White compared with 47 different species at Cutoff with two shared species between these two sites. There was no significant difference in the species richness between the two sites or the three topographic features. Species richness among the topographic features within site however was significantly different (Table 1). Within a study site only Bob White ridges and Bob White swales were not significantly different. Across study site only Bob White swales and Cutoff swales were not significantly different, shown in Table 1.

There were only two species found at both study sites. The shared species were *Brunnichia ovata*, and *Juncus effusus*. A list of the most common and rare species at both sites and topographic features within site is shown in Table 2.

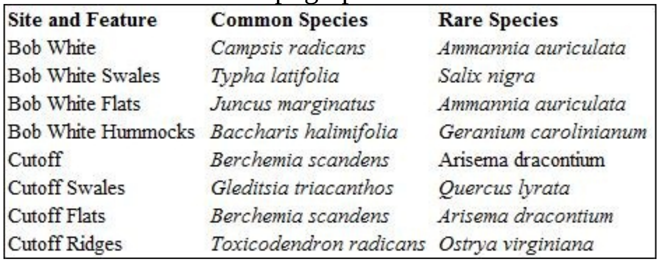
When comparing the two study areas, the Beta diversity was calculated as 76, with a Sorensen-Dice Similarity Index of 0.05, and a Jaccard/Tanimoto Coefficient of 0.03. Cutoff ridges had the greatest overall diversity, whereas flats had the highest diversity at Bob White as shown in Table 3.

Table 1. The p-values for species richness at each topographic feature within each site.



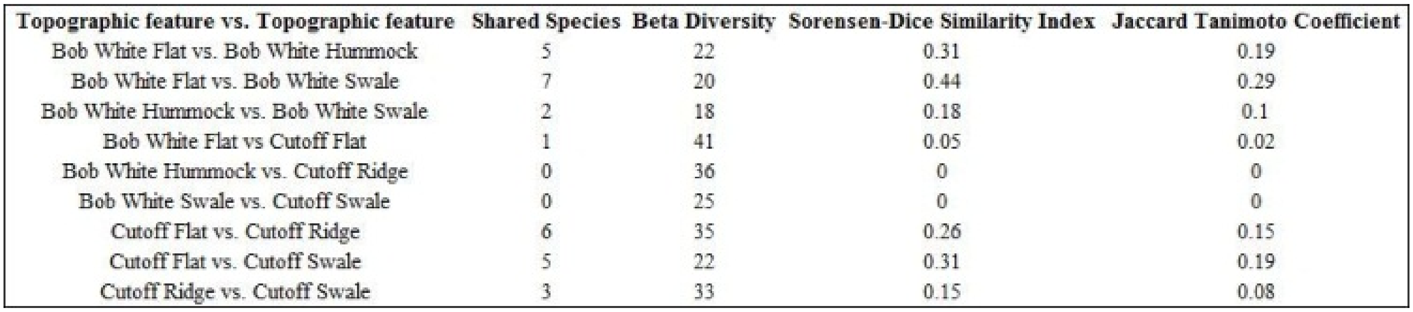
Site and Topographic Feature	Site and Topographic Feature	P-value
Bob White Swale	Bob White Flat	<0.01
Bob White Swale	Bob White Ridge	>0.05
Bob White Flat	Bob White Ridge	<0.01
Cutoff Swale	Cutoff Flat	<0.01
Cutoff Swale	Cutoff Ridge	<0.01
Cutoff Flat	Cutoff Ridge	<0.01
Bob White Swale	Cutoff Swale	>0.05
Bob White Flat	Cutoff Flat	<0.01
Bob White Ridge	Cutoff Ridge	<0.01

Table 2. List of the most common and rare species at each site and at each topographic feature within site.



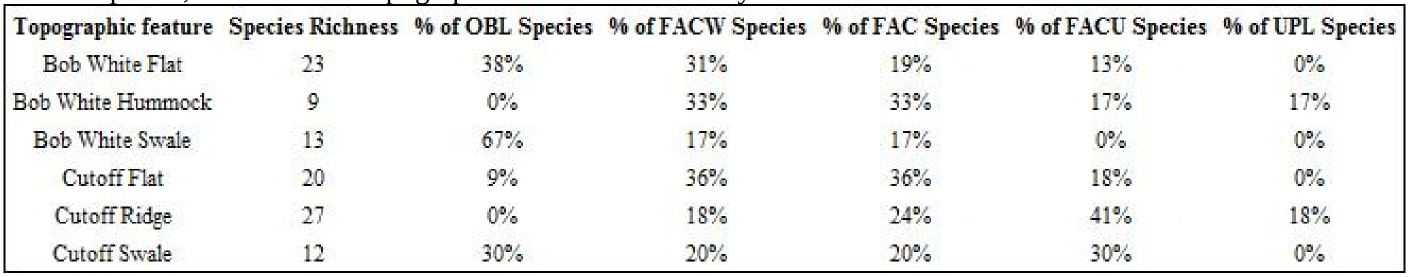
Site and Feature	Common Species	Rare Species
Bob White	*Campsis radicans*	*Ammannia auriculata*
Bob White Swales	*Typha latifolia*	*Salix nigra*
Bob White Flats	*Juncus marginatus*	*Ammannia auriculata*
Bob White Hummocks	*Baccharis halimifolia*	*Geranium carolinianum*
Cutoff	*Berchemia scandens*	Arisema dracontium
Cutoff Swales	*Gleditsia triacanthos*	*Quercus lyrata*
Cutoff Flats	*Berchemia scandens*	*Arisema dracontium*
Cutoff Ridges	*Toxicodendron radicans*	*Ostrya virginiana*

Table 3. The shared species, Beta diversity, Sorensen-Dice Similarity Index, Jaccard/Tanimoto Coefficient between each topographic feature and study site.



Topographic feature vs. Topographic feature	Shared Species	Beta Diversity	Sorensen-Dice Similarity Index	Jaccard Tanimoto Coefficient
Bob White Flat vs. Bob White Hummock	5	22	0.31	0.19
Bob White Flat vs. Bob White Swale	7	20	0.44	0.29
Bob White Hummock vs. Bob White Swale	2	18	0.18	0.1
Bob White Flat vs Cutoff Flat	1	41	0.05	0.02
Bob White Hummock vs. Cutoff Ridge	0	36	0	0
Bob White Swale vs. Cutoff Swale	0	25	0	0
Cutoff Flat vs. Cutoff Ridge	6	35	0.26	0.15
Cutoff Flat vs. Cutoff Swale	5	22	0.31	0.19
Cutoff Ridge vs. Cutoff Swale	3	33	0.15	0.08

Table 4. The species richness, percent OBL species, % of FACW species, % of FAC species, % of FACU species, % of UPL species, found at each topographic feature at each study site.



Topographic feature	Species Richness	% of OBL Species	% of FACW Species	% of FAC Species	% of FACU Species	% of UPL Species
Bob White Flat	23	38%	31%	19%	13%	0%
Bob White Hummock	9	0%	33%	33%	17%	17%
Bob White Swale	13	67%	17%	17%	0%	0%
Cutoff Flat	20	9%	36%	36%	18%	0%
Cutoff Ridge	27	0%	18%	24%	41%	18%
Cutoff Swale	12	30%	20%	20%	30%	0%

Of the plants identified to species, swales at both sites had the most plants and highest percentage of OBL species shown in Table 4. Two-thirds of plants identified to species were OBL or FACW species at Bob White. Only 34% of the species found at Cutoff were OBL or FACW species. Bob White flats had the highest number of individual species with a wetland indicator status of OBL or FACW. At Cutoff the topographic feature with the most OBL and FACW species were the swales.

Ipomoea wrightii (Wright's morning glory) and *Rumex crispus* (Curly dock) *Triadica sebifera* (Chinese tallow), and *Cardiospermum halicacabum* (Balloon vine) are introduced species found at Bob White. *T. sebifera* and *C. halicacabum* were not in any of the survey plots but was seen at the site. *Vicia sativa* (Common vetch) was the only introduced species at Cutoff.

Discussion

The results demonstrated that Bob White did not have a significantly different species richness from Cutoff even though species composition was different. Vegetation diversity differences are, however, common between restored wetlands and natural wetlands (Galatowitsch and van der Valk 1996, Ashworth 1997, Fennessy and Roehrs 1997). There were differences in species richness between the topographic features across site except for the swales. There should be a difference in plant diversity between the topographic features at both sites because it is accepted that hydrologic regime impacts plant diversity (Brinson et al. 1981, Keddy 2000). Flats had the highest species richness at Bob White which is supported by Simmons et al. (2011) and Bruland and Richardson (2005) who both reported greater plant species richness and diversity at intermediate elevation, flat areas. This is attributed to intermediate duration of hydroperiod, whereas swales and hummocks experience moisture extremes. These extremes in moisture may explain why there was not a significant difference in species richness between the swales and ridges at Bob White although the composition of the diversity was different. The flats shared the most species in common with swales and ridges/hummocks within study sites. The amount of shared species is likely because flats are a transitional landscape between the two topographic features and could have varying hydrologic regimes that do not favor swale or ridge/hummock species over the other. Strangely the shared species that were found were found at Bob White's flats and hummocks and Cutoff's flat and swales. This was unusual because the gradient of topographic features should have different hydrologic regimes, which should influence species composition. Bob White hummocks had the lowest species richness, while the ridges at Cutoff had the highest species richness. The presence of *B. halimifolia* may be the reason for the low richness at Bob White hummocks.

There were not many tree species at Bob White. Only *Salix nigra* was found in the survey plots but planted *T. distichum*, *Q. nigra*, *Q. lyrata*, *F. pennsylvanica*, and *Q. phellos* can be found at Bob White. *T. sebifera* has naturally invaded Bob White. Smith (2006) found a tree survival of zero trees per ha in the area where the topographic manipulations were done. In New Jersey a tree layer was not found at old-field sites in the coastal plain region until 25 years after abandonment (Hanks 1971). In addition Noon (1996) found no tree recruitment for the first 11 years following wetland creation on mineral soils of reclaimed mine lands. Battaglia et al. (2002) reported on a restoration site in the LMAV where ten species were planted. Fifteen years after planting there was a total of 16 tree and shrub species found at the site. After 16 years Battaglia et al. (2002) found a tree layer emerging from beneath the ground layer of vegetation. This shift in community is indicative of the transition phase between an old-field and young forest community (Bonck and Penfound 1945, Hopkins and Wilson 1974). A successful bottomland restoration project should include more than 15 woody species, such as oak, and hickory species (Allen 1990, 1997, Allen et al. 1998). Our study suggests that Bob White has not yet transitioned to a young forest community. One factor could be the presence of *B. halimifolia* (Groundsel bush). *B. halimifolia* was found within all topographic features of Bob White but was absent from Cutoff. Battaglia et al. (2008) found that *B. halimifolia* inhibits the regeneration of some plant species. This is consistent with many other studies that have shown that shrub species negatively interact with colonizing plants (Callaway 1992, Holl et al. 2000, Posada et al. 2000, Slocum 2001, Gomez-Aparicio et al. 2004, Zanini and Ganade 2005, Battaglia et al. 2008). Management of *T. sebifera* and *C. halicacabum* is suggested so they like *B. halimifolia* will not inhibit other plants from colonizing.

Woody vegetation generally takes longer to establish in created wetlands (Niswander and Mitsch 1995). De Steven et al. (2010) found that the cover of woody species in restored wetlands average 40% after five years and that restored sites had 53% of the same species in forested reference sites. Yepsan (2014) however found no correlation between time since restoration and percent of woody species. Seed banks and seed dispersal are the major sources of propagules in restored wetlands. However, the seed banks of farm fields are dominated by herbaceous species and often do not contain woody species (De Steven et al. 2006, Middleton 2003). Restored wetlands including Bob White are often surrounded by agricultural fields rather than forests, limiting dispersal of the propagules of woody species may explain their lower abundance in restored wetland (Herault and Thoen 2009, Kettenring and Galatowitsch 2011). Swales and flats are exceptionally isolated because they rarely receive overland flow of water from other wetlands, which leaves wind transport as the major source of woody propagules (Greene and Johnson 1996). Diversity in early succession is positively influenced by external dispersal of seeds (Pacala and Rees 1998). The previous land use history is important in determining the species composition of secondary forests (Grau et al. 1997, Chinea and Helmer 2003, Ito et al. 2004). Both sites in this study are surrounded by agricultural fields, and the dispersal rate should be low. Bob White does have a narrow riparian zone of trees that consists of animal or wind dispersed seed species surrounding the dike system that supplies the adjacent agricultural fields. This riparian area may be a source of seeds for Bob White but shortest distance from the surrounding patch of trees to one of the excavated swales is 230 m. The majority of preferred bottomland species density decreases at 60-80 m from a remnant forest but this issue decreases as the forests ages (Allen 1997, Brunet et al. 2000) as animal dispersion increases. Natural invasion should not be the only method of dispersion for plant species other than trees. Mid-story and shrub species should be planted; they are an important part of the natural forest structure.

At both sites and at all three topographic features there was a decrease in species richness over the study period. During the first survey in May water was still present at both sites which may have inhibited some plants from growing in the swales. The presence of water could explain why the inundated swales had an increase in diversity between the spring and summer surveys, as the presence of water may have inhibited some plants from growing early in the spring. Besides the changing of the seasons and a plant's natural life cycle causing a decrease in species richness over time there was also a dry spell from August 28th – October 19th, where only 1.8 cm of rain fell and 0.43 cm of that rain fell on October 9th (NADP 2016). This dry spell may have also been a factor in the loss of species richness over the time period of this study.

One indication that wetlands species are becoming reestablished at Bob White is that the swales had a significant proportion of OBL vegetation. Hydrophytic vegetation typically returns to a wetland 3-5 years after restoration begins (Erwin and Best 1985, Confer and Niering 1992, Reinartz and Warne 1993, Mitsch et al. 1998, Brown 1999). It had been 14 years after restoration at Bob White therefore the proportion of hydrophytes is to be expected. The U.S. Army Corps of Engineers (1987) stated that in order for a site to be considered to have a hydrophytic vegetation community the total number of species that are OBL, FACW and FAC+ must equal at least 50%. Examining just OBL and FACW species, Bob White Swales and Flats and Cutoff Swales met this criterion. The hummocks at Bob White also do not have any OBL species but have UPL species suggesting that swale excavation was successful at forming a landscape with diverse hydrology and therefore a wide range of plant species. OBL species are indicative of wetlands and ecosystem services (Naeem et al. 1999). Bob White may be providing ecosystem services since ecosystem

The time frame for a restored bottomland hardwood forest to resemble a natural bottomland hardwood forest can take decades (Kusler 1986, Mitsch and Gosselink 1993, King et al. 2006). Cutoff is in the range of 50-100 years old on average. Bob White's restoration began in 2001; it is therefore unreasonable to expect Bob White to resemble a natural bottomland forest at this point in time. According to Frenkel and Morlan (1991) success of forested wetlands should not be judged until 15-50 years after restoration. It is too early to tell if Bob White has been a success because the factor one uses to determine success will determine whether or not restoration has been successful. To determine if Bob White will be successfully restored more studies like this should be conducted.

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Food Habits of Green Tree Frogs (*Hyla* cinerea) from Arkansas

C.S. Thigpen*, H. Dodson, and S.E. Trauth

[1]Department of Biological Sciences, Arkansas State University P.O. Box 599, State University, AR 72467

*Correspondence: christopher.thigpen@smail.astate.edu

Running Title: Food Habits of Green Treefrogs

Abstract

We analyzed stomach contents of 120 Green Tree Frogs, *Hyla cinerea*, collected between May 1956 and October 2014 in Arkansas. Beetles and arachnids were the predominant prey item; the next most abundant groups were Diptera and Hemiptera. Vegetable matter was also found in several frogs. All identifiable vegetable matter was determined to be of the genus *Persicaria*, colloquially known as smartweed. Our data suggests that Green Tree Frogs in Arkansas predominantly feed on beetles and arachnids, but occasionally ingest plant matter when actively foraging.

Introduction

Most amphibians are opportunistic carnivores stimulated by movement and will eat anything they can swallow (Duellman and Trueb 1986, Stebbins and Cohen 1995). The ingestion of non-prey material may be deliberate or incidental during foraging. Any non-prey item that appears to be prey may be ingested.

Amphibians often ingest vegetable or mineral matter during foraging (Korschgen and Moyle 1955, Linzey 1967, Hedeen 1972, Silva et al. 1989, Hirai and Matsui 1999). Fishing lures (Stebbins and Cohen 1995), stones (Engelbert et al. 2008), and vegetable matter (Hamilton 1948, Oliver 1955, Silva et al. 1989, Fialho 1990, Stebbins and Cohen 1995 and Thigpen et. al 2015) have been found in anuran stomachs. Silva et al. (1989) and Fialho (1990) believe frogs could act as seed dispersers.

Herein, we present findings of the food habits of Green Tree Frogs from Arkansas. This study is intended to describe the diet of the Green Tree Frog in Arkansas and encourage further studies of amphibian diets to produce a better understanding of their natural history within the state.

Materials and Methods

One hundred and twenty individuals collected between May 1956 and October 2014 were accessed from the Arkansas State University Museum of Zoology Herpetological Collection. The frogs were measured from snout to vent and stomachs were excised. The stomachs were emptied and placed into 70% v/v ethanol along with the contents. Stomach contents were photographed, categorized into animal, vegetable, or mineral categories, and identified to lowest achievable taxonomic level.

Results

Of the 120 stomachs examined, 74 (62%) contained food items. Of those 74 stomachs, 60 contained animal matter, 42 contained vegetable matter and one contained mineral matter.

Table 1. Food Items Removed from Stomachs

Food	Freq. in Stomachs (n = 120)	Number of Items
Unidentified Animal Matter	0.033	4
Arachnida	0.133	16
Coleoptera	0.242	29
Collembola	0.008	1
Diptera	0.100	12
Dermaptera	0.008	1
Hemiptera	0.092	11
Hymenoptera – others	0.042	5
Hymenoptera - Formicidae	0.033	4
Lepidoptera	0.067	8
Malacostraca	0.008	1
Orthoptera	0.075	9
Unidentifiable Veg. Matter	0.333	40
***Persicaria* sp.**	0.025	3
Mineral Matter	0.008	1

Many stomachs contained multiple items of animal matter and plant matter and often contained several individuals of each order. Animals were identified in 56 of the stomachs. Plant material was identified in 2 of the 42 stomachs containing vegetable matter. The plant items were identified as the fruits of *Persicaria*, a common emergent aquatic plant colloquially known as smartweed. All of the unidentifiable plant material consisted of pieces of leaves, stems, or flowers. No intact plant material, other than the fruits of *Persicaria* sp., was found. The single mineral was miniscule and could not be identified. However, it appeared to be a small translucent stone most likely from a sandy substrate.

Discussion

In the cases of many of the empty stomachs, food could be seen in the intestines, but was not retrieved as it was degraded by digestion. Volume was not determined for the stomach contents as digestion had begun in many stomachs and many prey items were not intact. The common occurrence of vegetable matter in the stomachs might be caused by incidental ingestion during foraging, but the frequency warrants further study. Plants may be ingested during times of low prey abundance as seen by Silva et al. (1989) as a means to supplement the diet. These frogs may ingest vegetable matter when prey is scarce to supplement their diets, similar to the findings Silva et al. (1989). Further studies throughout the year may provide some insight. The lack of ingested minerals is likely caused by the arboreal nature of the species. However, mineral ingestion may be common during the breeding season when the animals are foraging. Lithophagy is fairly common in ranid frogs (Hirai and Matsui 1999, Engelbert et al. 2008) and accidental ingestion may be increased in hylids with terrestrial foraging. It is likely that green treefrogs do ingest vegetable matter fairly often, but future studies are needed to quantify the phenomenon.

Overall, the diet of Green Tree Frogs in Arkansas is similar to the diets of Green Tree Frogs in other areas. Spiders and beetles were commonly found in frog stomachs in other studies (Haber 1926, Kilby 1945, Freed 1982, Meshaka 2001, and Leavitt and Fitzgerald 2009) and were also a common prey item in this study. Hymenopterans, ants or otherwise, also seem to comprise much of the diet of Green Tree Frogs in Texas (Leavitt and Fitzgerald 2009), Florida (Kilby 1945, Freed 1982, and Meshaka 2001), and Georgia (Haber 1926) and in Arkansas (this study). Hemipterans are also a common prey item in Florida (Freed 1982 and Meshaka 2001), Georgia (Haber 1926), and Arkansas (this study). Comparisons of the diets of these frogs from 4 states indicate that spiders, beetles, and ants/wasps might be a staple in the diet of Green Tree Frogs throughout their range.

However, these studies also suggest that the frogs will supplement their diets with other prey items dependent upon prey availability. Dipterans were a common prey item in Florida (Kilby 1945 and Meshaka 2001) but less common in Georgia and Texas. In this study, they were found in 10 percent of the stomachs. Lepidopterans were common in stomachs of frogs from Georgia (Haber 1926), but rare in Florida (Kilby 1945, Freed 1982, and Meshaka 2001) and Arkansas (this study). Orthopterans were common in Arkansas (this study), Georgia (Haber 1926), and Texas (Leavitt and Fitzgeral 2009) but rare in Florida (Kilby 1945, Freed 1982, and Meshaka 2001).

Based on these occurrences, it is likely Green Tree Frogs have common staple prey items, supplemented with other prey items abundant in their habitat, and these supplemental prey items should vary between different habitats, states, etc.

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Long-term Monitoring and Recovery of a Population of Alligator Snapping Turtles, *Macrochelys temminckii* (Testudines: Chelydridae), from a Northeastern Arkansas Stream

S.E. Trauth[1*], D.S. Siegel[2], M.L. McCallum[3], D.H. Jamieson[4], A. Holt[5], J.B. Trauth[6], H. Hicks[7],
J.W. Stanley[1], J. Elston[8], J.J. Kelly[9], and J.D. Konvalina[1]

[1]*Department of Biological Sciences, Arkansas State University, State University, AR 72467-0599*
[2]*Department of Biology, Southeast Missouri State University, One University Plaza, MS 6200, Cape Girardeau, MO 63701*
[3]*School of Agriculture and Applied Sciences, Langston University, Langston, OK 73050*
[4]*Biology Department, Crowder College-Cassville, 4020 North Main, Cassville, MO 65625*
[5]*University of Arkansas Community College at Morrilton, 1537 University Blvd., Morrilton, AR 72110*
[6]*2213 Byrnewood, Jonesboro, AR 72404*
[7]*4106 Maple Street, North Little Rock, AR 72118*
[8]*4400 West University Blvd., Apartment 14201, Dallas, TX 75209*
[9]*7351 Hoover, Apartment 3N, Richmond Heights, MO 63117*

[*]Correspondence: strauth@astate.edu

Running Title: Long-term Monitoring of Alligator Snapping Turtles

Abstract

We conducted a mark-recapture study of Alligator Snapping Turtles, *Macrochelys temminckii*, on Salado Creek (Independence Co., Arkansas) during 10 trapping seasons, which spanned a 20-year period (1995–2015). We trapped a total of 163 Alligator Snapping Turtles during 416 trap nights and recorded a total of 35 recaptures during this study. Both the catch per unit effort (CPUE) and Jolly-Seber approaches demonstrated that this population benefitted from removal of harvest pressure, thus leading to an increase in abundance of Alligator Snapping Turtles in the lower ~5 km of the creek. The CPUE averaged slightly greater than 0.24 (317 trap nights) during the first 4 years (1995–1998). The CPUE also showed an increase to 0.64 by 2001 (only 14 trap nights), and then dramatically increased during the final 5 years to 0.92 (85 trap nights). The population size estimates during the early period of the study (1995–2001) ranged from 20 turtles in 1995 to as many as 88 turtles in 1998, whereas the population size estimates from 2011-2015 ranged from 105 turtles in 2011 to as many as 282 turtles in 2015. Within our sample, recaptured males grew faster on average than females or juveniles in both straight carapace length and mass. These data, however, should be used with caution as age was not known. Most of the recaptured Alligator Snapping Turtles exhibited some degree of site fidelity.

Introduction

The Alligator Snapping Turtle, *Macrochelys temminckii*, is North America's largest freshwater turtle. As a long-lived species, males greatly outweigh females and can often reach a massive body size (e.g., greater than 120 kg; Pritchard 2006). Because turtle meat has long been a culinary staple for humans worldwide (Liner 2005), the conservation status of Alligator Snapping Turtles has become a paramount issue in recent years. Decades of widespread exploitation by commercial trappers on this species in several southern states has led to an apparent overharvesting of this turtle (Pritchard 1989), which subsequently brought about its current protection and legal status throughout most of its distribution (Reed et al. 2002).

Species recovery is a complex and case-specific process, often requiring conservation actions that attempt to offset the drivers of extinction (Hoffmann et al. 2010). Management of long-lived organisms, such is the case with species of chelydrid turtles poses a particularly difficult monitoring challenge (Congdon et al. 1994, Reed et al. 2002). For example, short-term investigations of populations of snapping turtles may be hampered simply because the animals themselves may outlive their field studies (Gibbs and Steen 2005). Long-term investigations, on the other hand, may require sampling protocols that extend well beyond the lifespan of researchers (Reed et al. 2002). Long-term investigations, however, are especially important because they provide information on life history parameters that can affect management decisions related to turtle populations subjected to commercial harvesting (Congdon et al. 1994).

Long-term field studies on Alligator Snapping Turtles were initiated in the early 1990s in Arkansas and Missouri in response to reports by their game and fish agencies (Wagner et al. 1994-Arkansas Game and Fish Commission; Santhuff 1993-Missouri Department of Conservation) indicating declines in populations. These studies revealed depressed population numbers; however, both states lacked sufficient information on the population ecology of this species to adequately address management concerns. Consequently, each state set forth to create a population database to better understand the species status.

In Arkansas, Trauth et al. (1998) conducted a preliminary short-term study (1995–1997; 352 trap nights yielding 98 turtles), which examined the population structure of Alligator Snapping Turtles in 3 northeastern Arkansas creeks. They reported size-class differences in 2 of the 3 creeks and attributed a lack of adult turtles to previous harvesting. Howey and Dinkelacker (2013) trapped 103 turtles in a central Arkansas stream from 2005 to 2007 and found several factors impeding population recovery. In 2009, Lescher et al. (2013) re-trapped six sites previously documented by Santhuff (1993) in Missouri and found significantly fewer turtles at all 6 locations. Shipman and Riedle (2008), in another study in southeastern Missouri, captured 37 turtles from 4 sites (out of 19 visited) in 2 counties. They found a significant difference in turtle size when comparing turtles taken from historic collection sites exploited by commercial trappers vs. non-historic, unexploited sites. Additional status and/or distributional surveys in other states (e.g., Alabama—Folt and Godwin 2013; Oklahoma—Riedle et al. 2005, East et al. 2014) reported low CPUE of Alligator Snapping Turtles when compared to the numbers documented in Arkansas and Missouri.

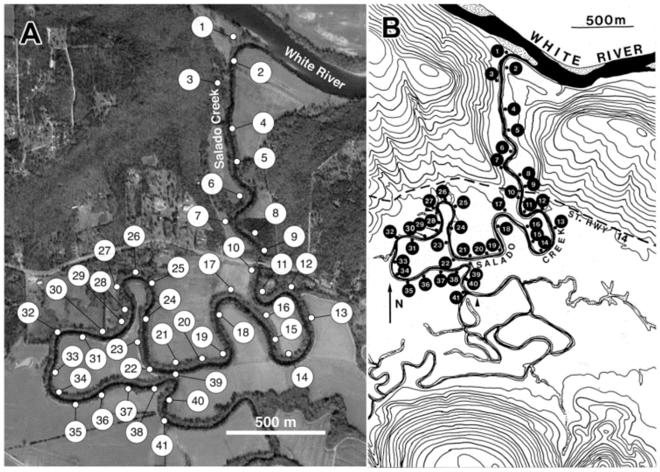

Figure 1. Designated trapping locations superimposed onto physiographic (A) and topographic (B) images of lower Salado Creek, Independence Co., Arkansas. Arrowhead (in B) points to an unnavigable region of the creek. (Image in A derived from Google Earth©). Cultivated agricultural fields (pale areas in A) immediately surround much of the lower region of the creek.

The objectives of the present study were to report the findings of a long-term investigation (1995–2015) on a population of Alligator Snapping Turtles inhabiting a single creek (Salado Creek) in northeastern Arkansas. Salado Creek had experienced heavy commercial trapping of Alligator Snapping Turtles prior to 1993, the year in which prohibition of commercial harvesting of the species was enforced by the Arkansas Game and Fish Commission. We present data on abundance, population structure, capture/recapture rates, body condition, growth rates, trapping success, site fidelity, and movement patterns. These data, acquired from trapping results gleaned from 10 separate years over a span of 20 years of sampling within Salado Creek, extend our critical knowledge database on this turtle in Arkansas and provide vital information, range-wide, for managers making prudent status decisions regarding this species.

Materials and Methods

Study site

Salado Creek (Fig. 1) is a mostly upland watershed located within the Boston Mountains (Interior Highlands Ecoregion) of the southwest corner of Independence Co., Arkansas. The creek twists and loops greatly after dropping from the higher elevations and is normally navigable by motorized boat only within the lower 5.0 km stretch of water.

The creek empties into the White River (fed by the hypolimnetic, cold-water release from two U.S Army Corps of Engineers lake impoundments) at a point approximately 9.8 air km southeast of the White River bridge at Batesville at an elevation of approximately 73 m. Access to the creek was secured from a public boat-launching ramp just below Lock and Dam No. 1 at Batesville. The lower stretch of the creek (sampled for turtles) can be characterized as a turbid, free-flowing, steep-banked stream, nestled 2–5 m below the rim of its deciduous tree and brush-laden banks. Submerged stumps, numerous root wad entanglements, and creek bank slides were observed yearly. We never witnessed any bank overflows on the creek following heavy rain events. Creek depth generally varied between 2–4 m; width ranged from 8–20 m. Depth was lowest during late summer. Log jams and freshly fallen trees often blocked the waterway (Fig. 2) and eventually prevented access to the uppermost reaches of the creek (i.e., trapping locations above No. 33; see Fig. 1). Arkansas State Highway 14 spans 5 m above the creek at a point approximately 1.5 km upstream from the White River.

Salado Creek mostly lacks a typical floodplain along much of its lower stretch, as agricultural fields abut its bank rim (Fig. 1A).

Figure 2. Fallen trees often created temporary logjams across Salado Creek. The trunks of these trees ultimately contribute to the microhabitat and overall cover for Alligator Snapping Turtles.

Forty-one trapping locations were initially assigned to Salado Creek at the beginning of the study in August 1995 (Fig. 1). Linear distance between designated locations averaged 160 m. Locations 34–41 became inaccessible during the 1996 trapping season due to a permanent logjam above location 33; these locations were not visited thereafter.

Trapping methods

We primarily used 1.2 m diameter, double-throated, hoop nets containing a 6.5 cm mesh spread between 7 fiberglass rings for trapping turtles. Nets were set with extended anterior and posterior lead lines running parallel to the bank (net mouth downstream and submerged). Lead lines were fastened to natural vegetation (i.e., trees and/or root systems) or to steel and wooden stakes. Nets were baited with recently-thawed whole fish or fish parts (mostly buffalo [*Ictiobus* sp.]), which were tied to the most posterior hoop using a nylon string strung onto a 16-penny nail used to secure the bait. A breather space was provided at the end of each trap using a gallon plastic flotation jug.

Traps (normally 12 or 13 per sampling episode) were set in late afternoon, left overnight, and then checked the following morning. No traps were left for two consecutive nights. A trap night was defined as a single trap left overnight; the capture rate, CPUE, was determined by dividing the number of turtles by the number of trap nights.

Turtle processing procedures

For permanent identification, all Alligator Snapping Turtles were tagged with passive integrated transponder (PIT) tags hypodermically injected ventrolaterally into the postanal tail musculature. The following body parameters were measured: straight carapace length (SCL, in mm), preanal tail length (PTL, in mm), postanal tail length (in mm), and body mass (BM, in kg). The massive body size of several males trapped on 24 July 2015 prevented measurements of BM (See Fig. 3; Appendix 1). Turtles were released at or near the point of capture. Because curved carapace length (CCL), instead of SCL, was used to measure turtles during the initial part of the present study (Trauth et al. 1998), we computed a linear regression equation using 28 turtles from which we measured both CCL and SCL (turtles captured during 2011-2014). The resulting equation, $Y = 1.0474X - 9.7831$, where X = SCL and Y = CCL, was generated. We then converted the CCL measurements to SCL of the turtles from 1995–1998 in order to create uniformity in our overall database.

Dobie (1971) found that Louisiana male and female turtles mature at around 370 and 330 mm SCL, respectively. However, the assignment of sex to live subadult turtles is a difficult task due to the absence of marked sexual differences in morphology in young turtles. We utilized a standard method for sexing Alligator Snapping Turtles—if the cloacal (anal) opening of an individual's straightened tail appeared to lie posterior to the posterior margin of the carapace when viewed ventrally, then the specimen was considered a male; the opposite case would indicate a female. We also utilized PTL to assign sex to subadults: males were considered to possess a longer PTL relative to body size and females, a shorter PTL relative to body size. If there was no clear distinction between the sexes using PTL in subadults, the specimen remained unsexable and was labeled a juvenile.

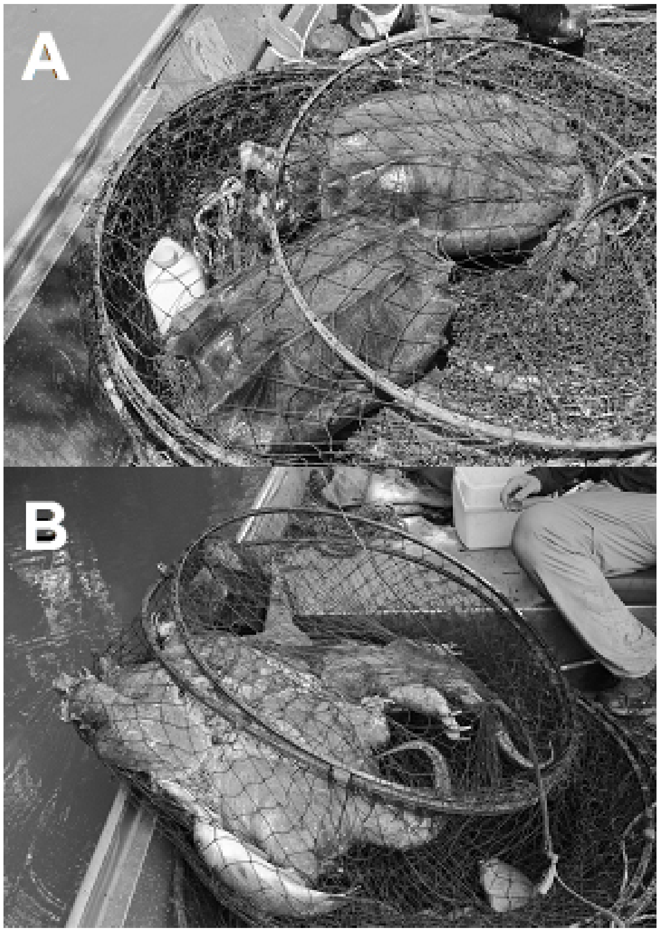

Figure 3. Several large male Alligator Snapping Turtles at trap locations 19 (A) and 17 (B) from Salado Creek photographed on 24 July 2015. No BM measurements were taken from these males (see Appendix 1).

Statistical analyses

Population size was estimated using Microsoft Excel to calculate the Jolly-Seber population model (Jolly 1965; Seber 1982). Population growth was estimated using linear regression of the CPUE (turtles caught per trap-night) during each sampling year from 1995-2015. Population growth of males and of females was also examined using multiple regression with trap-nights and years as predictors because of the complex pattern of population growth compared to males. Jolly-Seber is suited for studies like the present one, in which every individual has the same probability of capture during a given sampling period, the same probability of survival among sampling periods, marks are relatively permanent, and sampling time is negligible in relation to the intervals between samples. In addition, it assumes an open population, thus allowing for immigration, emigration, mortality, and natality (Krebs 1989).

Male and female SCL-BM (body mass) relationships were modeled using regression for all turtles captured during the study. Change in SCL and in body condition of recaptured Alligator Snapping Turtles was statistically analyzed using linear regression. Body condition was estimated by dividing the body mass (kg) by the SCL.

In all analyses, alpha = 0.05 was significant, alpha = 0.1 indicated no significant effect, and alpha > 0.05 but < 0.01 suggested a possible effect. This method of decision theory follows accepted convention for ecological studies.

Results

Relative abundance

We trapped 163 individual Alligator Snapping Turtles over 416 trap nights and recorded a total of 35 recaptures during this study (Appendix 2). Two turtles drowned, and one turtle that was caught by a fisherman in the White River upstream from Salado Creek, was released into the creek. The CPUE averaged slightly greater than 0.24 (317 trap nights) during the first 4 years (1995–1998), showed an increase to 0.64 by 2001 (only 14 trap nights), and then dramatically increased during the final 5 years of this study to average 0.92 (85 trap nights).

Population structure

There was a significant size class difference between the early trapping period vs the more recent period (Fig. 4). Males and females falling into the 351–400 mm SCL range comprised the greatest number of turtles. A shift toward greater body size in males was evident in the 2011–2015 sampling period.

Population size

For 1996–2001, the average population size estimate in the sampled portion of Salado Creek was 58 (SE = 14.26) Alligator Snapping Turtles. No population estimate is provided for 1995, because there were no previously marked turtles for that year. The population size estimates ranged from 20 in 1995 to 88 in 1998. For 2011–2015, the average population size estimate in the sampled portion of Salado Creek was

131 (SE = 39.71) turtles. The population size estimates ranged from 105 in 2011 to 282 in 2015.

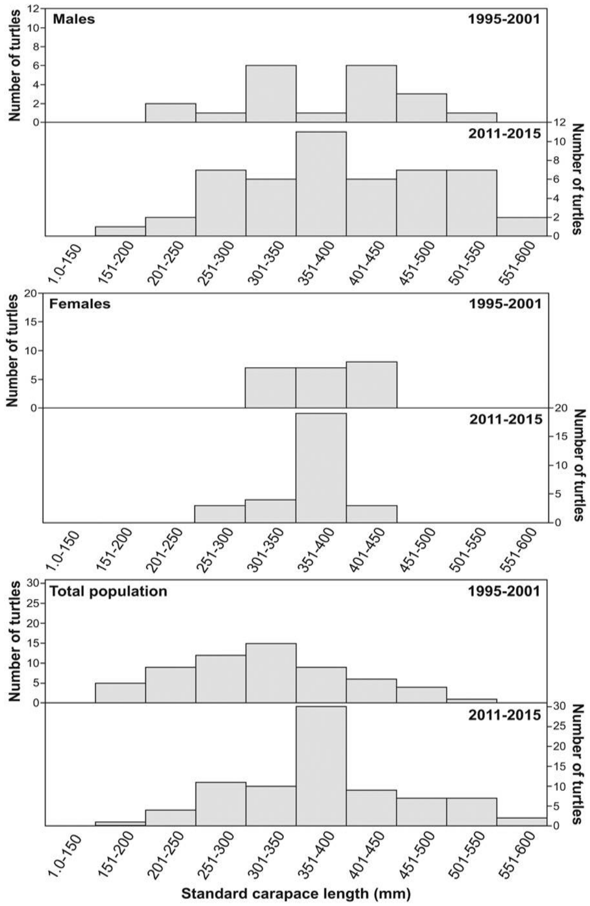

Figure 4. Size-class distribution of Alligator Snapping Turtles trapped during 10 trapping seasons from Salado Creek.

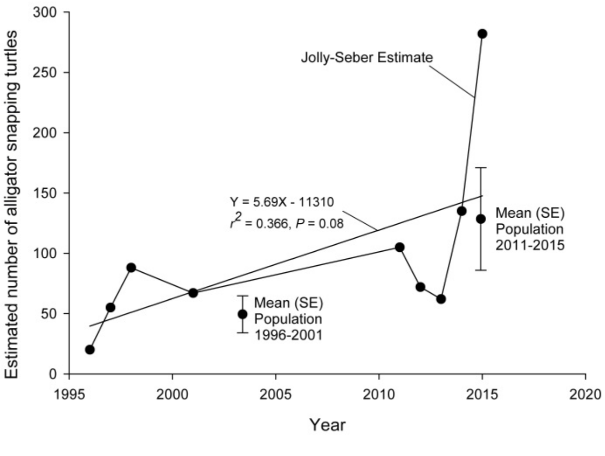

Figure 5. Average population size in the two sampling periods, annual number of Alligator Snapping Turtles trapped, and the regression demonstrating growth in the population in from Salado Creek.

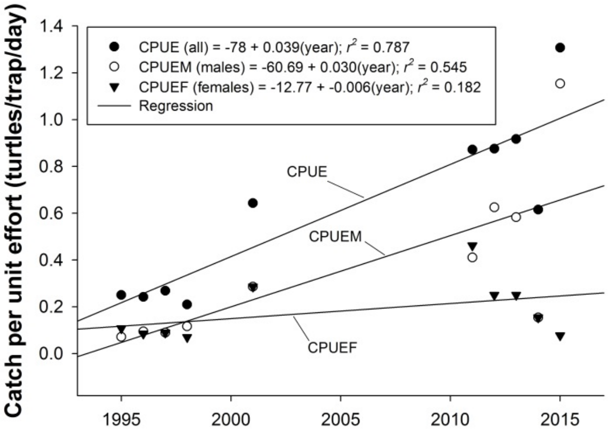

Figure 6. Change in abundance of Alligator Snapping Turtles trapped from Salado Creek based on catch per unit effort (CPUE) over the course of our long-term monitoring.

The population in the lower 5.0 km of Salado Creek grew significantly from an estimated 5.5–174 turtles/km in 1995–2001 (Fig. 5) to an estimated 21.9−290 turtles/km in the ending sampling period (2011–2014).

Did CPUE change during the study?

The CPUE of Alligator Snapping Turtles increased during 1996–2015 (CPUE = [0.039 x year] - 78.4; r^2 = 0.787; Fig. 6). The CPUE during 1995 – 2001 grew from 0.322 turtles/trap/night (SE = 0.081) to 0.917 turtles/trap/night (SE = 0.11) in 2011–2015 (Fig. 7; T = –4.33, P = 0.003).

Males became more abundant during the study (CPUE = [0.03 x year] -60.7; r^2 = 0.545; Fig. 6). The CPUE for males grew marginally larger from 0.13 (SE = 0.039) in 1995-2001 to 0.585 (SE = 0.16) in 2011–2015 (Fig. 7; T = –2.68, P = 0.055).

Females abundance was erratic during the study (r^2 = 0.182; Fig. 6). Although CPUE of females grew from 1995–2011, it regressed from 2011–2015. Multiple regression suggests that some growth in the female population probably occurred ($N_{females}$ = [0.09 x trap-nights] + [0.18 x year] – 353; r^2 = 0.496). However, CPUE in 1995–2001 (mean = 0.1272, SE = 0.40) was not significantly different from CPUE during the 2011–2015 trapping period (mean = 0.238, SE = 0.065; Fig. 7; T = –1.46, P = 0.193).

Did SCL and body condition (BC) change during the study?

Males were recaptured more frequently than were females, thus analyzing these data together may be suspect. The relationship for BM (kg) to SCL (mm) in males ($r^2 = 0.972$; Fig. 8) was $BM_{male} = 13.24 – (0.114 \times SCL_{male}) + (0.0003 \times SCL^2_{male})$ and for females ($r^2 = 0.745$; Fig. 8) was $BM_{female} = 14.40 – (0.120 \times SCL_{female}) + (0.0003 \times SCL^2_{female})$.

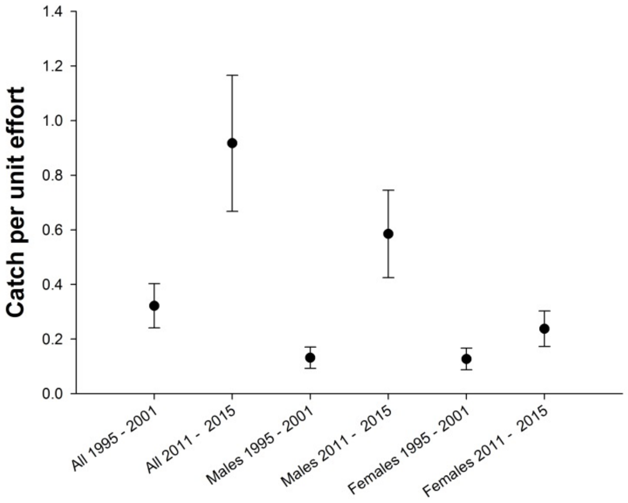

Figure 7. Trapping success for male and female Alligator Snapping Turtles from Salado Creek based upon CPUE.

The SCL for recaptured males showed an average increase of 105 mm (SE = 27.6) ($r^2 = 0.771$, slope = 0.84 mm/mo; Fig. 9; Appendix 1) from 322.4 mm (SE = 34.3) to 427.4 mm (SE = 20.2). Overall male body condition also increased 0.02 (SE = 0.004) ($r^2 = 0.685$; slope = 0.0001 units/mo; Fig. 10) from 0.028 (SE = 0.006) to 0.044 (SE = 0.005). The BM-SCL relationship for all males marked suggests that the expected BM for the average SCL observed in the early sampling period should be 7.67 kg, which is 1.25 SE below the observed BM (11.37 kg, SE = 3.45).

The model predicts the BM for the recaptured males in the second sampling period should be 19.3 kg, which is well within the observed BM (19.7 kg, SE = 2.9) for recaptured males.

The SCL for recaptured females increased 12.17 mm (SE = 5.8) ($r^2 = 0.510$; slope = 0.159 mm/mo; Fig. 7) from 340.8 mm (SE = 7.2) to 353 mm (SE = 9.3). Female body condition rose 0.003 units (SE = 0.0004) ($r^2 = 0.257$; slope = 7.2×10^{-6}; Fig. 10) from 0.027 units (SE = 0.027) to 0.03 units (SE = 0.001). The BM-SCL relationship for all females marked suggests that the predicted BM for the SCL observed in the early sampling period should be 8.35 kg, which is 1.58 SE lower than the observed BM (9.22 kg, SE = 0.55) for females from the early sampling period that were

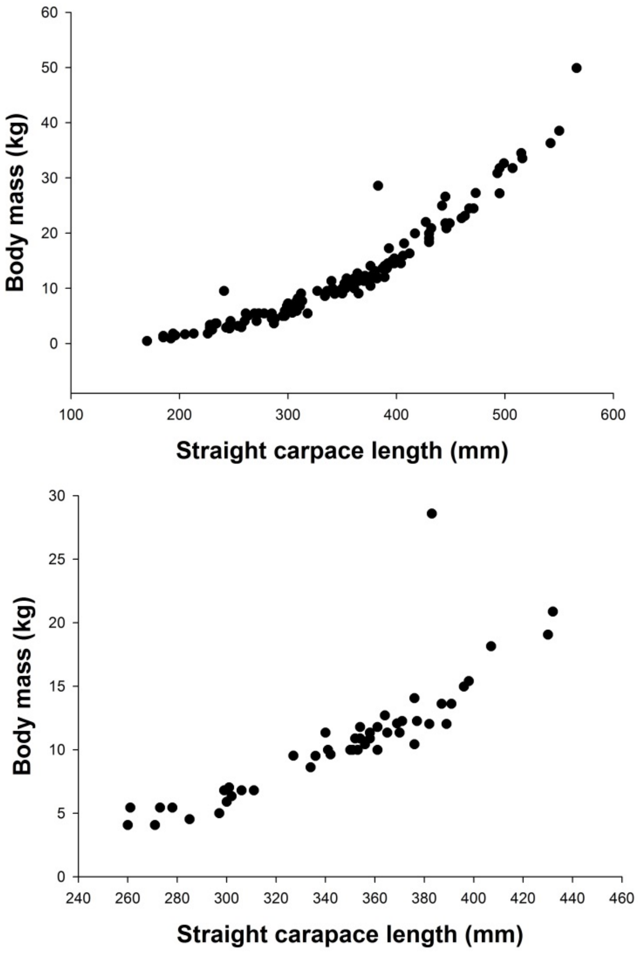

Figure 8. Relationship between body mass and straight carapace length in males (upper plot) and female (lower plot) Alligator Snapping Turtles from Salado Creek.

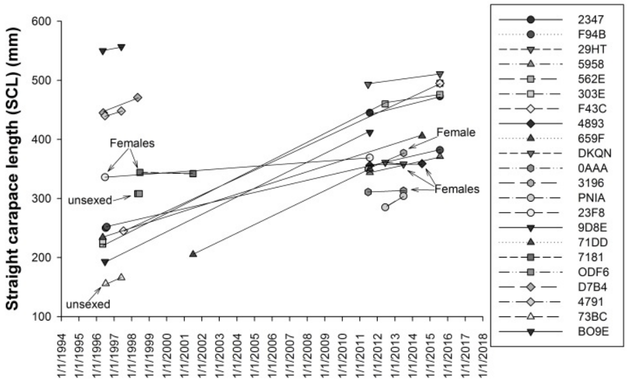

Figure 9. Change in straight carapace length in recaptured Alligator Snapping Turtles from Salado Creek (see also Appendix 1).

The SCL for recaptured females increased 12.17 mm (SE = 5.8) ($r^2 = 0.510$; slope = 0.159 mm/mo; Fig. 7) from 340.8 mm (SE = 7.2) to 353 mm (SE = 9.3).

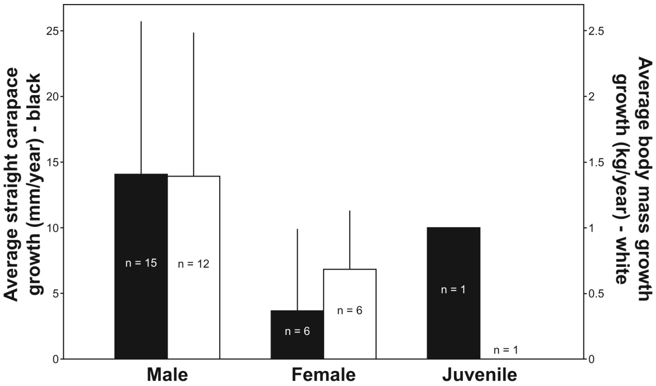

Figure 10. Body condition of male, female, and juvenile Alligator Snapping Turtles from Salado Creek

Female body condition rose 0.003 units (SE = 0.0004) (r^2 = 0.257; slope = 7.2×10^{-6}; Fig. 10) from 0.027 units (SE = 0.027) to 0.03 units (SE = 0.001). The BM-SCL relationship for all females marked suggests that the predicted BM for the SCL observed in the early sampling period should be 8.35 kg, which is 1.58 SE lower than the observed BM (9.22 kg, SE = 0.55) for females from the early sampling period that were later recaptured. The model predicts the BM for the recaptured females in the second sampling period should be 9.42 kg, which is 1.8 SE lower than the observed BM (10.7 kg, SE = 0.71) for recaptured females.

Growth rate

The male turtles recaptured had a higher average growth rate in both straight carapace length and mass (Fig. 10) than in females or juveniles. These data, however, should be used with caution as age was not known. However, these data are most likely not representative of the growth rates of males and females as turtle age was not possible to record (also see Moore et al. 2012). Males with a starting SCL below 300 mm exhibited high growth rates (19.85 mm/year; n = 7) from time of first capture to next capture while males over 300 mm exhibited relatively low growth rates (7.37 mm/year; n = 8). No female under 300 mm SCL was recaptured; thus, the difference in growth rates between the sexes is undoubtedly, in part, due to size at first capture, which is most likely correlated to age at first capture.

One recaptured male had a puzzling growth rate. The specimen (F94B; Appendix 1) was first captured on 10 July 1996 and then 20 years later on 24 July 2015. The latter date yielded body measurements that were not compatible with other males recaptured during the same time frame (e.g., specimen 562E). This unusual male had a SCL of 382 mm, a PTL of 130 mm, and a BM of ca. 11.8 kg, whereas 562E had a SCL of 476 mm, a PTL of 195 mm, and a BM of at least 28 kg (actual mass not measured). Body measurements for a comparable female trapped on 24 July 2015 were of expected values (SCL = 376 mm; PTL = 83 mm; BM = 10.4 kg).

Trapping success

We documented trapping success rate based upon trap location and distance upstream from the White River (Fig. 11; Appendix 3) We found that trap locations downstream from St. Hwy 14 (starting just below location 10) were the least productive. Fifty-one trap nights in this lower region of the creek yielded only 3 turtles (CPUE = 0.06). Although trap locations 14–24 were trapped the most intensely and were the most productive, turtle-wise, yielding 125 turtles during 236 trap nights (CPUE = 0.53), traps 25–33 produced the highest CPUE (0.67) during 40 trap nights. Traps 10–13 produced only 20 turtles (CPUE = 0.24) during 85 trap nights. Trapping success was clearly related to distance away from the White River (Fig. 11).

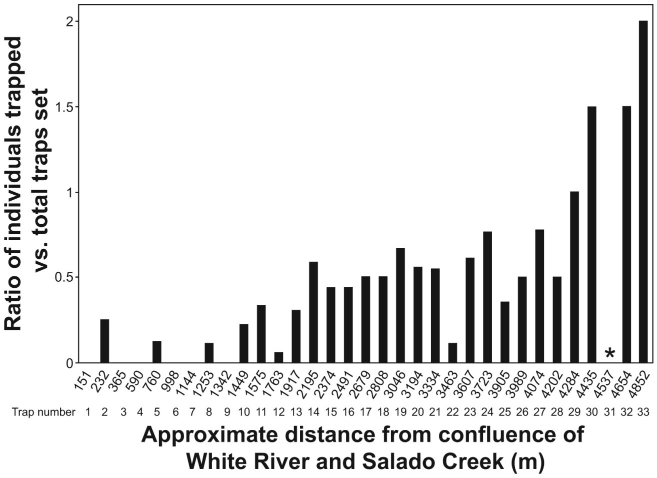

Figure 11. Trapping success of Alligator Snapping Turtles from Salado Creek based upon turtle captures. (*No traps were set at trap location 33.)

Site fidelity and movements

Most of the 22 recaptured Alligator Snapping Turtles (following the 1996 trapping season) exhibited some degree of site fidelity. Females, however, ventured farther away from a particular trap location more often and to a greater distance than did males (Appendix 1). Eight of 14 males showed a preference to remain at a locality (i.e., within the expanse of 1–2 trapping locations). Surprisingly, one subadult male (F94B) was captured on 10 July 1996 at trap location 24 and recaptured at the same location on 24 July 2015. Moreover, another subadult male (71DD), taken from trap location 18 on 2 July 2001, was recaptured at the same location on 26 July 2011. One of the largest adult males (BO9E), however, moved from trap location 19 on 10 May 1996 to location 24 on 30 May 1997 (a distance of 9.71 km). Females, on the other hand, were less inclined to remain in a particular area of the creek. For example, an adult female (4893) was captured at trap location 23 on 26 July 2011 and recaptured 17 July 2014, approximately 1.76 km downstream, at location 11. Another adult female (3196) moved in the opposite direction, going from trap location 14 on 26 July 2011 to location 21 on 27 June 2013 (a distance of approximately 0.96 km). These are but a few examples of the movement patterns exhibited by Alligator Snapping Turtles detected by our mark-recapture technique. (For seasonal movement patterns of Alligator Snapping Turtles in Salado Creek in 1996, see Trauth et al. 1998).

Discussion

A plethora of field studies generated in recent years has sought to address concerns over the legal status as well as the lack of relevant life history information on wild and reintroduced populations of Alligator Snapping Turtles throughout the species' range (Reed et al. 2002; Riedle et al. 2005, 2006, 2008a, 2008b, 2009; Shipman and Riedle 2008; Howey and Dinkelacker 2009; Bogosian 2010; East et al. 2013; Folt and Godwin 2013; Howey and Dinkelacker 2013; Lescher et al. 2013; Moore et al. 2013; Anthony et al. 2015). Our study, however, is the first mark-recapture investigation to examine a single, historically harvested population through an extended long-term monitoring period.

Declines in some turtle populations have been linked to the removal of the largest turtles for human consumption, regardless of sex (Nickerson and Pitt 2012). We found that the population structure of Alligator Snapping Turtles in Salado Creek shifted toward larger body size and greater numbers in both adult males and females greater than 325 mm SCL, but especially in adult males, during the 2011-2015 sampling years—an indication that some stability had returned to this population following a major depletion of larger individuals (Trauth et al. 1998). In addition, the sex ratio strongly favored males (1.8:1) during the latter sampling period, and the overall sex ratio for the study (1.4:1) also remained in favor of males. In contrast, Howey and Dinkelacker (2013), in their 2005-2007 sampling period in a central Arkansas stream found a sex ratio in favor of females (1:6.1). Likewise, Folt and Godwin (2013) in Alabama also recorded a sex ratio in favor of females (1:1.8). One might easily conclude that, in these particular cases, harvesting large adult males contributed to these observed female-biased sex ratios (as mentioned in both studies). At present, however, it is unclear why sex ratios favored males in Salado Creek, although Howey and Dinkelacker (2013) suggest that female-biased sex ratios could be the result of a suite of conditions from unequal hatchling sex ratios and differential immigration and emigration to differential mortality of the sexes and possibly trap bias (Gibbons 1990). The unexpected and very striking 15:1 sex ratio in favor of adult males found in our single day of sampling in 2015, however, requires additional explanations and plausibly contradicts a previous suggestion that intra-sex competition could contribute to female-biased ratios due to an increased mortality rate in males (Harrel et al. 1996).

A comparison of the Salado Creek population size with that found in a comparable eastern Oklahoma study (East et al. 2013) revealed major differences in numbers at the beginning and at the end of sampling. In our study, a shift toward greater numbers and larger turtles occurred; however, in Oklahoma, just the opposite was true as that population experienced an overall decline. For example, our 2011–2015 data resembles that published by Riedle et al. (2008) for their 1997–2000 densities, whereas our 1995–2001 population numbers roughly matched the 2010–2011 data published by East et al. (2013). With respect to size-class structure, our study found an increase in number of turtles in the 351–400 mm SCL range, and East et al. (2013) found that size range was highly underrepresented.

Our overall CPUE was 0.39; however, we found a steady rise in CPUE from 0.24 (1995–1998) to 0.92 during the final 5 years of this study. In reporting a CPUE of 0.478 for the Fowl River in Alabama, Folt and Godwin (2013) suggested that their value there possibly represented historic population conditions prior to commercial trapping, although they attributed this greater relative abundance partially to a paired-net method of trapping. This value was much greater than their overall CPUE value of 0.062.

We found that both CPUE and Jolly-Seber approaches demonstrate that the Salado Creek population benefitted from removal of harvesting pressure, thus leading to an increase in abundance of Alligator Snapping Turtles. These data indicate a sharp increase in the number of all sizes of turtles compared to previous findings from this population (Trauth et al. 1998).

Our results indicate that recaptured males had higher BC scores by the end of the study. However, the BC was much higher in the early period than it was in the later period relative to the model's prediction. This suggests that males are now experiencing more stress than earlier. The improvement in female body condition may reflect alleviation of stress from fishing pressure or other unknown factors during the study, although turtles in both periods appeared well nourished. In fact, the females in this population appeared well nourished (i.e., higher BCI) in both sampling periods with females in the second sampling period exhibiting a 12.2% higher BCI than observed in the early sampling period. Because males seem to be experiencing reduced relative body condition and females are more nourished, we can speculate that this may reflect increased male-male competition and aggression as the growing male population leads to increased opportunities for interactions, aggression and competition. Male-male competition could result from an interspecific source. Johnston et al. (2012) mentioned the possibility that in their population of *Chelydra serpentina*, agonistic encounters between *C. serpentina* and *Macrochelys temminckii* might be occurring, given the number of Alligator Snapping Turtles (n = 84) they trapped and the necessity for the two species of chelydrids to coexist. We captured a relatively small number of *C. serpentina* (n = 6) during our study and have no supportive evidence to indicate any encounters. Interestingly, however, one of these was an adult male reported by McCallum and Trauth (2003), which was PIT tagged in 1996 and recaptured at the very same trap location (10) in 2001. The turtle had experienced a reduction in post-anal tail length of 18 mm; the tail also appeared to have healed and had regrown from the initial injury.

One of the more salient outcomes from our study pertained to site fidelity and habitat selection. A majority of recaptured males were trapped at or near their original collection site. One extreme example was a 20-year span between recaptures for a male at the same trapping location. Howey and Dinkelacker (2009) reported that males and females probably select similar habitats (submerged structure) having similar thermal properties. A majority of turtles captured during our study was trapped upstream from location 14. Submerged logs, root wads, and tree stumps were generally available throughout most parts of the creek; however, the lower stretch (below location 10) was presumably impacted by the cooler water of the White River and represented suboptimal thermal conditions for the turtles. Our trapping success in this region was the lowest value for the entire creek.

A reduced vagility in most recaptured turtles was observed (based upon recaptures during the 2011-2015) when compared to the considerable upstream and downstream movements found in 1996 (Trauth et al. 1998). Adult females, however, appeared to move more than adult males; this observation was similar to the results found in southeast Missouri (Shipman and Riedle 2008). Linear home ranges of the Missouri turtles were much larger than those in our study, which may account for and/or play a role in movement behavior. This new finding does suggest, however, that Alligator Snapping Turtles may venture away from preferred microhabitat sites when population numbers are low or when searching for a mate, but will return to and/or remain within a familiar microhabitat when population numbers stabilize or when mates are easily accessible. Food availability was never considered a contributing factor in addressing movement patterns in these turtles in Salado Creek primarily, because of an assortment of fishes (mostly *Ictiobus* sp.) was always a by-catch of our trapping efforts. Our observations on movement patterns of Alligator Snapping Turtles confined within a mostly "closed" creek population differed sharply from most other studies examining movements in this species (e.g., Riedle et al. 2006). Consequently, in order to understand the wide variations in turtle movements, future studies might benefit greatly by investigating this turtle strictly in a creek habitat similar to ours.

Acknowledgments

We thank the Arkansas Game and Fish Commission, and especially Kelly Irwin, for written permission to investigate Alligator Snapping Turtles in Salado Creek through the authority of annual Scientific Collection Permits granted to SET. The Department of Biological Sciences at Arkansas State University provided financial assistance during this study; J. D. Wilhide, B. J. Ball, C. Lewis, H. H. Trauth, and K. S. Trauth assisted in the field. Chris Thigpen kindly offered technical assistance during manuscript preparation; we also thank J. D. Riedle for his constructive comments on the manuscript and for the sharing of his knowledge about Alligator Snapping Turtles. Lastly, we dedicate this paper to the memory of Robert "Champ" Williams, Arkansas videographer and Emmy-award winning marine documentarian, who drowned 8 November 2015 in a filming tank while gathering underwater footage of a large Alligator Snapping Turtle.

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Appendix 1. Mark-recapture data on 22 alligator snapping turtles sampled from Salado Creek (1996–2015) including PIT tag identification code (last 4 alpha-numerics of the original code), date of capture, trap location, sex, straight carapace length, and body mass.

*Specimen (PIT Tag ID); Date of Capture – (Trap Location)	Sex	Straight Carapace Length (mm)	Body Mass (kg)		*Specimen (PIT Tag ID); Date of Capture – (Trap Location)	Sex	Straight Carapace Length (mm)	Body Mass (kg)
2347	M				3196	F		
26 Jul 2011 –(20)		445	21.79		26 Jul 2011 –(14)		350	9.98
24 Jul 2015 –(24)		473	27.26		27 Jun 2013 –(21)		377	12.25
F94B	M				PNIA	M		
10 Jul 1996 –(24)		250	3.85		12 Jun 2012 –(17)		285	4.99
1 Aug 1996 –(23)		252	4.08		27 Jun 2013 –(17)		304	5.67
24 Jul 2015 –(24)		382	11.79		23F8	F		
29HT	M				26 Jun 1996 –(24)		336	9.52
21 Jun 2011 –(20)		493	30.84		26 Jul 2011 –(23)		369	12.07
24 July 2015 –(19)		511	-		9D8E	M		
5958	M				26 Jun 1996 –(18)		193	1.13
26 Jul 2011 –(18)		344	9.52		26 Jul 2011 –(20)		412	16.33
24 Jul 2015 –(19)		371	12.25		71DD	M		
562E	M				2 Jul 2001 –(18)		205	1.68
10 May 1996 –(16)		233	3.63		26 Jul 2011 –(18)		350	9.07
12 Jun 2012 –(17)		460	22.70		7181	F		
24 Jul 2015 –(19)		476	-		24 Jun 1998 –(29)		334	8.62
303E	M				2 Jul 2001 –(24)		342	9.62
10 May 1996 –(16)		228	2.86		ODF6	?		
24 July 2015 –(17)		452	-		8 May 1998 –(27)		308	5.90
F43C	M				8 Jun 1998 –(29)		308	5.90
17 Jul 1997 –(14)		245	3.20		D7B4	M		
24 Jul 2015 –(15)		495	27.21		22 May 1996 –(17)		445	23.59
4893	F				8 May 1998 –(27)		471	24.49.
26 Jul 2011 –(23)		356	10.43		4791	M		
17 Jul 2014 –(11)		359	11.34		26 Jun 1996 –(20)		440	20.86
659F	M				30 May 1997 –(25)		448	21.77
10 May 1996 –(14)		234	3.63		73BC	?		
17 Jul 2014 –(11)		406	15.88		10 Jul 1996 –(23)		156	0.45
DKQN	F				30 May 1997 –(24)		166	0.45
12 Jun 2012 –(18)		361	9.98		BO9E	M		
27 Jun 2013 –(24)		358	11.34		10 May 1996 –(19)		550	38.55
0AAA	F				30 May 1997 –(24)		557	41.73
21 Jun 2011 –(23)		311	6.80					
27 Jun 2013 –(21)		313	7.71					

*Does not include 14 recaptures (11 turtles) from 1996

Appendix 2. Yearly sampling data for alligator snapping turtles from Salado Creek (*Excludes recaptures; **Excludes multiple recaptures.)

Year	Total No. of Trap Nights	Total No. of Trapped Alligator Snapping Turtles	*Sex Ratio (male:female)	**No. of Recaptures	Catch Per Unit Effort (CPUE)
1995	28	7	2:3	0	0.25
1996	190	46	18:16	15	0.24
1997	56	15	5:5	7	0.27
1998	43	9	5:3	2	0.21
2001	14	9	4:4	0	0.64
2011	39	34	16:18	4	0.87
2012	8	7	5:2	1	0.88
2013	12	11	7:3	4	0.92
2014	13	8	3:2	2	0.62
2015	13	17	15:1	7	1.31
Totals	416	163	80:57	35	$\bar{x} = 0.62$

Appendix 3. Trapping success at 32 trap locations (no traps set at location 31) on Salado Creek.

Trap Location	Total Number of Traps Set at Location	Total Number of Turtles Trapped at Location		Trap Location	Total Number of Traps Set at Location	Total Number of Turtles Trapped at Location
1	3	0		18	28	14
2	4	1		19	21	14
3	4	0		20	18	10
4	6	0		21	22	12
5	8	1		22	18	2
6	7	0		23	18	11
7	3	0		24	17	13
8	9	1		25	17	6
9	7	0		26	4	2
10	27	6		27	9	7
11	18	6		28	2	1
12	17	1		29	3	3
13	23	7		30	2	3
14	29	17		31	0	0
15	16	7		32	2	3
16	25	11		33	1	2
17	28	14		Totals	416	*175

*Includes recaptured turtles.

Vertebrate Natural History Notes from Arkansas, 2016

R. Tumlison[1*] C.T. McAllister[2], H.W. Robison[3], M.B. Connior[4]
D.B. Sasse[5], D.A. Saugey[6], and S. Chordas III[7]

[1]*Department of Biology, Henderson State University, Arkadelphia, AR 71999*
[2]*Division of Science and Mathematics, Eastern Oklahoma State College, Idabel, OK 74745*
[3]*9717 Wild Mountain Drive, Sherwood, AR 72120*
[4] *Northwest Arkansas Community College, One College Drive, Bentonville, AR 72712*
[5]*Arkansas Game and Fish Commission, 213A Highway 89 South, Mayflower, AR 72106*
[6]*Nightwing Consulting, PO Box 52, Jessieville, AR 71949*
[7]*Center for Life Sciences Education, The Ohio State University, 260 Jennings Hall, 1735 Neil Avenue, Columbus, OH 43210*

*Correspondence: tumlison@hsu.edu

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Abstract

Often, interesting and important observations of vertebrate distribution and natural history are not published because they are not part of a larger study. Knowledge of small details, however, not only fills gaps in understanding but also lead researchers to interesting questions about ecological relationships or environmental change. We have compiled recent observations of importance that can add immensely to the growth of knowledge of the biology of vertebrates in Arkansas.

Introduction

Vertebrate field biology constantly changes as land use alters the environment and non-native species establish among native forms. Distribution and natural history of many species within Arkansas is still not well understood or documented, but we have been developing a series of articles to update the state of knowledge of the natural history of Arkansas's vertebrates (e.g. Tumlison *et al*. 1992; Tumlison and Robison 2010; Connior *et al*. 2011, 2012, 2013, 2014; Tumlison *et al*. 2015). Herein, we include previously unreported records of distribution, parasites, reproduction, food habits, disease, and other aspects of natural history of the vertebrates of Arkansas. All vertebrate voucher specimens are deposited in the vertebrate collections at Henderson State University (HSU).

Methods

Some fishes were collected by use of 3.1 × 1.8 m or 6.1 × 1.8 m seines with 3.2 mm mesh, or by use of a backpack electroshocker. Other fishes were collected by use of the Missouri Trawl (Herzog and Hrabik 2012), which is designed to skim the bottom of streams and rivers where no other gear can be effectively deployed. Specimens were preserved in 10% formalin and stored in 45% v/v isopropanol, or photographic vouchers were taken. Localities are reported as GPS (latitude and longitude) coordinates when available.

Bat records are based on identification of specimens sent to the Arkansas Department of Health (ADH) for rabies testing, or from field records of mist-netting activities by experienced researchers with release of captured animals on site following data collection. Observers names (initials if one of the authors) are provided in appropriate accounts.

Results and Discussion

CLASS ACTINOPTERYGII

Acipenseridae – Sturgeons

Scaphirhynchus platorhynchus (Rafinesque) – Shovelnose Sturgeon. On 16 October 2015, 2 adult and 1 juvenile *S. platorhynchus* were collected in a Missouri Trawl deployed in the Mississippi River at Sans Souci Landing S of Osceola, Mississippi County (35.655427°N, 89.925932°W). This is only the second record of *S. platorhynchus* from this portion of the Mississippi River in Arkansas (Robison and Buchanan 1988). Etnier and Starnes (1993) show 3 records of this sturgeon across from Arkansas on the Tennessee side of the river. Photographic vouchers were taken of these specimens.

Hiodontidae – Mooneyes

Hiodon alosoides (Rafinesque) – Goldeye. Ten adult *H. alosoides* were collected on 16 October 2015 in a Missouri Trawl from the Mississippi River at Sans Souci Landing S of Osceola, Mississippi County (35.655427°N, 89.925932°W). There is a pre-1960 record of the Goldeye N of the present site just off the Mississippi River, as well a single record just W of this site, but not in the mainstem river (Robison and Buchanan 1988). There are several records of *H. alosoides* on the Tennessee side of the river across from our site (Etnier and Starnes 1993). Photographic vouchers were taken of the specimens.

Cyprinidae – Minnows and Carps

Chrosomus erythrogaster (Rafinesque) – Southern Redbelly Dace. Robison and Buchanan (1988) reported a breeding season for *C. erythrogaster* from April through May. On 7 July 2015, 3 females (67, 71 and 75 mm TL) containing ripe eggs were collected by HWR and CTM with backpack electroshocker from Calico Creek at Calico Rock, Izard County (36.122557°N, 92.143797°W). Apparently, this inhabitant of cold springs and spring-fed streams can prolong spawning under favorable environmental conditions.

Cyprinella venusta Girard – Blacktail Shiner. A single adult (88 mm TL) of 8 *C. venusta* collected with seine from the Arkansas River at Pendleton Bend Park, Desha County (33.987451ºN, 91.362222ºW), on 1 July 2014 by CTM and RT was parasitized by the copepod, *Lernaea cyprinacea* L. This is the first report of *L. cyprinacea* from this host. Delco (1962) previously reported a similar species, *L. catostomi* from *C. venusta* in Texas.

Hybopsis amnis Hubbs and Greene – Pallid Shiner. On 25 August 2015, 7 adult *H. amnis* were collected from Big Creek (34.847292°N, 91.010262°W), a site located off AR St. Hwy 78, Lee County, by R.A. Hrabik. *Hybopsis amnis* is an uncommon cyprinid in Arkansas where Robison and Buchanan (1988) reported no previous localities for this shiner from Lee County and only 2 records in the upper St. Francis River for all of northeastern Arkansas (McAllister *et al*. 2010). With this present collection, we suggest the pre-1960 disjunct populations in the upper St. Francis River reported by Robison & Buchanan (1988) in extreme northeastern Arkansas may actually still exist. However, additional surveys in the St. Francis upstream of Lee County and to the Missouri border are recommended.

Lythrurus fumeus (Evermann) – Ribbon Shiner. Numerous adult *L. fumeus* were collected on 25 August 2015 from Big Creek (34.847292°N, 91.010262°W) located off AR St. Hwy 78, Lee County by R.A. Hrabik. While common in the Coastal Plain region of southern Arkansas, there are fewer records of *L. fumeus* in northeastern Arkansas and none previously from Lee County (Robison and Buchanan 1988).

Macrhybopsis hyostoma (Gilbert) – Shoal Chub. On 16 October 2015, 4 adult *M. hyostoma* were collected from the Mississippi River at Sans Souci Landing S of Osceola, Mississippi County (35.655427°N, 89.925932°W), by use of the Missouri Trawl. While rare in other regions of Arkansas, *M. hyostoma* is more common in the Mississippi River where there are 2 previous records just N of our site (Robison and Buchanan 1988). This chub is common across the Mississippi River along the Tennessee border (Etnier and Starnes 1993). Photographic vouchers were taken of the specimens.

Macrhybopsis meeki (Jordan and Evermann) – Sicklefin Chub. Six specimens of the rare large river cyprinid *M. meeki*, were collected from the Mississippi River at Sans Souci Landing S of Osceola, Mississippi County (35.655427°N, 89.925932°W), on 16 October 2015 by use of the Missouri Trawl. There is only one previous record of *M. meeki* in the state: specimens collected near Blytheville in Mississippi County (Carter and Beadles 1983, Robison and Buchanan 1988). On the Tennessee side of the river, Etnier and Starnes (1993) also note a single record for *M. meeki*. Photographic vouchers were taken of the specimens.

Notropis boops Gilbert – Bigeye Shiner. On 6 July 2015, a 66 mm TL female *N. boops* was collected by HWR and CTM with backpack electroshocker in the Mulberry River at Campbell Cemetery, Franklin County (35.656272°N, 93.858909°W). This female was full of ripe orange eggs and marks the first documentation of ripe eggs in *N. boops* in the state. Reproduction of *N. boops* has not been studied in Arkansas. In Oklahoma, *N. boops* spawns from late April into August (Lehtinen and Echelle 1979). Tuberculate males have been collected in Arkansas from May to July (Robison and Buchanan 1988).

Pimephales tenellus (Girard) – Slim Minnow. A single adult *P. tenellus* parasitized by the copepod *Lernaea cyprinacea* L was collected with backpack electroshocker from the Ouachita River at Rocky Shoals, Montgomery County, on 13 October 2015 by HWR and CTM.. This is the first report of *L. cyprinacea* from this host.

Semotilus atromaculatus (Mitchill) – Creek Chub. The Creek Chub is a generalized carnivore feeding on a variety of invertebrates including crayfish, molluscs, diatoms and insects, and small fishes (Robison and

Buchanan 1988). No food habits studies have been conducted on this species in Arkansas. On 5 July 2015, a 130 mm TL male S. *atromaculatus* was collected by HWR and CTM with backpack electroshocker in Washita Creek, Johnson County, ca. 3.2 km S of the Mulberry River bridge at AR St. Hwy 103 (35.654197°N, 93.593527°W). Analysis of food items consumed revealed a juvenile cicada, which is a terrestrial insect and marks the first time this prey item has been documented from a Creek Chub.

Catostomidae – Suckers

Moxostoma erythrurum (Rafinesque) – Golden Redhorse. Golden Redhorse are reported to feed on bottom ooze, algae, insect larvae, and small molluscs (Robison and Buchanan 1988). On 22 July 2014, an adult Golden Redhorse was collected with boat electrofisher at Crooked Creek at Kelly's Slab (36.244433°N, 92.716531°W) SW of Yellville, Marion County. Examination of gut contents revealed 2 aquatic mites, *Lebertia* sp. (male and female). This is the first report of mites from the gut contents of the Golden Redhorse.

Ictaluridae – Catfishes

Noturus maydeni Egge – Black River Madtom. The Black River Madtom has been described within the last decade from Arkansas (Egge and Simons 2006) as individuals were formerly considered to be Ozark Madtom (*Noturus albater*). Little is known about the life history of this madtom. On 8 July 2015, a 94 mm TL female *N. maydeni* full of ripe eggs was collected by HWR and CTM with backpack electroshocker from Town Creek at Salem off AR St. Hwy 9, Fulton County (36.37109°N, 91.821027°W). This marks the first documentation of the timing of spawning of this madtom in Arkansas.

Percidae – Perches

Etheostoma pulchellum (Agassiz) – Plains Darter. A gravid female *E. pulchellum* (50 mm TL, 1.41 g weight) was collected on 4 March 2016 by CTM from the Rolling Fork River, Sevier County (34.064667°N, 94.380023°W). It contained 195 ripe eggs which weighed 0.34 g. Nothing is known about spawning in Arkansas; however, in Texas, the spawning season of this darter occurs from mid-October through July (Hubbs and Armstrong 1962, Marsh 1980, Hubbs 1985). Female *E. pulchellum* produce from <50 to up to 200 eggs/season (Hubbs 1985). In addition, male *E. pulchellum* from the same locality possessed well-developed breeding colors.

Etheostoma sp. cf. spectabile (Agassiz) – Ozark Darter. Recently, the *E. spectabile* complex of "orangethroat" darters has been separated into several species (Ceas and Page 1997). We report here reproductive information that relates to the "Ozark" form, which has not yet been described as a new species, thus we use the available scientific name with this caveat.

In Arkansas, spawning of *E. spectabile* was reported to occur from mid-February to early June (Robison and Buchanan 1988). On 7 July 2015 a 50 mm TL female *E. spectabile* with ripe eggs was collected by HWR and CTM with backpack electroshocker from Calico Creek at Calico Rock, Izard County (36.122557°N, 92.143797°W). This discovery extends the breeding season in the state by a full month.

Etheostoma whipplei (Girard) – Redfin Darter. Southern populations of this darter were elevated by Piller *et al*. (2001) to full species (Redspot Darter *Etheostoma artesiae*), leaving the upland populations in the Ouachitas and Ozarks as Arkansas' representatives of *E. whipplei*. On 7 July 2015 a 70 mm TL male *E. whipplei* in well-developed breeding coloration was collected by HWR and CTM with backpack electroshocker from Washita Creek, Johnson County, ca. 3.2 km S of the Mulberry River bridge at AR St. Hwy 103 (35.654197°N, 93.593527°W). Robison and Buchanan (1988) collected breeding adults in mid-March to late April in Arkansas. This documentation extends the possible breeding season to July in Arkansas.

CLASS AMPHIBIA

Plethodontidae – Lungless Salamanders

Desmognathus monticola Dunn – Seal Salamander. The seal salamander was introduced from the eastern United States (Georgia) and has established a breeding population in the Spavinaw Creek drainage in Benton County (Bonett *et al*. 2007, Connior *et al*. 2013a). Between 21 February and 15 November 2015, 29 *D. monticola*, 2 *Eurycea tynerensis* and 1 *E. longicauda melanopleura* were collected and necropsied for prey items. Snout-vent lengths for the 8 male *D. monticola* averaged 41.6 mm (range 30-64) and for the 18 females averaged 33.2 mm (range 28-42).

Table 1 provides the first report of foods of *D. monticola* in Arkansas. Three *D. monticola* had no food items, and the mean number of items per stomach was 3.8 for the 8 males and 9.8 for the 18 females. The female mean is high due to 66 items (mostly adult

Chironomids) in 1 stomach and 32 in another (mostly *Lirceus sp*. isopods and adult Chironomids). Even without those specimens considered, the female mean was 4.9 items per stomach.

The majority of the prey items for *D. monticola* were aquatic isopods (Isopoda) and both adult and larval midges (Chironomidae). One native salamander, *E. longicauda,* collected syntopically with the *D. monticola*, had consumed one gastropod and 2 Collembolans (one each of Sminthuridae and Entomobryidae). Two specimens of another native species, *E. tynerensis,* had consumed 15 Chironomidae larvae (plus one adult) and one *Lirceus sp.* isopod. These foods were consistent with those reported by Tumlison *et al*. 1990 for this salamander, and indicate dietary overlap and potential competition between the native species and the recently established non-native *D. monticola*. The impact of this non-native salamander on native species warrants further evaluation.

Ranidae – True Frogs

Lithobates areolatus circulosus (Rice and Davis) **–** Northern Crawfish Frog. The Northern Crawfish Frog inhabits extreme northwestern Arkansas through the Arkansas River Valley and to the southeastern corner of the state (Trauth *et al*. 2004). Knowledge regarding its biology is limited due to its secretive habits. On 13 March 2016, MBC found an adult male crawfish frog near Maysville (Benton Co.) that was completely missing its front left limb (Fig. 1). Tumlison *et al.* (2015) reported on the breeding ecology of this same site, but did not mention any limb malformations of other specimens. The exact cause of the malformation is unknown, but possibly due to an unsuccessful predation attempt early during development (Ballengée and Sessions 2009).

CLASS MAMMALIA

ORDER CHIROPTERA

Vespertilionidae – Vesper Bats

Unless otherwise noted, the new county distributional records reported here were gleaned from bats submitted for rabies testing by the Arkansas Department of Health (ADH), Little Rock.

Myotis grisescens A. H. Howell – Gray Bat. An adult male was found hanging above the door frame of a fire station in North Little Rock, Pulaski County, on 1 October 2015. A male gray bat was captured by DBS in a mist net over Mud Creek in Sec. 29, T21N, R1E, in Randolph County on 9 August 2015. The next night 4 females and 1 male were captured at the same site.

Nycticeius humeralis (Rafinesque) – Evening bat. An adult male was submitted from Waldron, Scott County on 19 August 2015; an adult male was submitted from Forrest City, St. Francis County, on 7 August 2015; a juvenile male was submitted from Ozark, Franklin County, on August 13, 2014.

Table 1. Food items recovered from stomachs of 26 specimens (8 males, 18 females) of *Desmognathus monticola* collected from Spavinaw Creek, Benton County, Arkansas, from February to November 2015.

Food Item	# in males	# in females
Diptera		
Chironomidae (larvae)	10	29
Chironomidae (adults)	1	85
Psychodidae		2
Stratiomyidae		1
Tipulidae	3	3
unidentified adult fly	1	2
Isopoda		
Ascellidae (*Lirceus sp.*)	7	41
Coleoptera		
Staphylinidae	1	1
Dytiscidae unid.	1	
Dytiscidae (*Heterosternuta sp.*)	1	1
Dytiscidae (*Neoporus sp.*)	1	
Unidentified		1
Collembola		
Entomobryidae	1	2
Sminthuridae		4
Odonata		
Cordulegasteridae (*Cordulegaster sp.*)	2	
Hemiptera		
Veliidae (*Microvelia sp.*)	1	
Aphididae		1
Rhyparochromidae (*Myodocha serripes*)		1
Unidentified		1
Homoptera		
Cicadellidae		3
Lepidoptera (larvae)	1	1
Orthoptera		1
Annelida Oligochaeta	1	1
Hymenoptera		
Formicidae	4	
Tricoptera		1
Nematoda		1

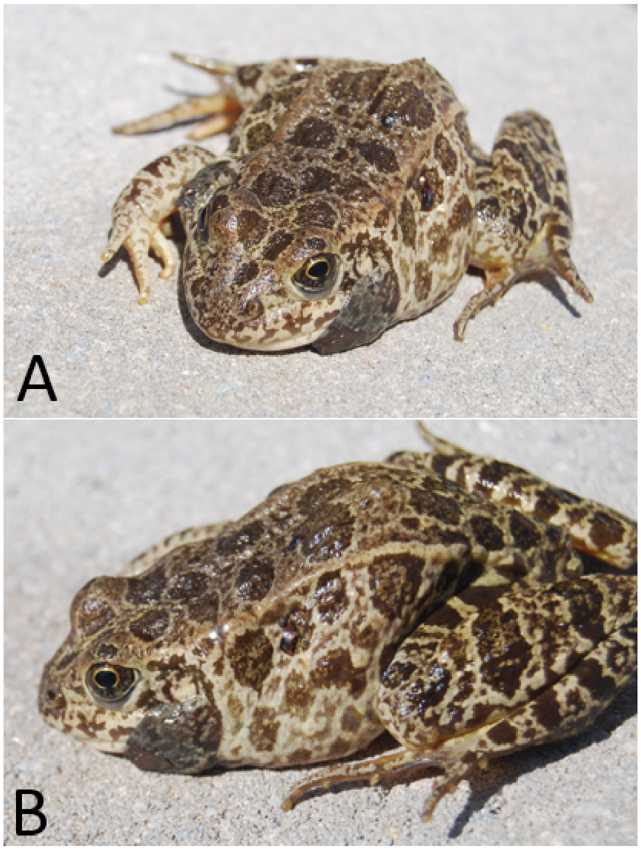

Figure 1. Adult male crawfish frog (Lithobates areolatus circulosus) collected from the vicinity of Maysville, Benton County, Arkansas, that is missing the left front leg. A. front view. B. side view.

Lasionycteris noctivagans (Le Conte) – Silver-haired Bat. A rabid male was submitted from Hagarville, Johnson County, on 8 June 2015.

Perimyotis subflavus F. Cuvier – Tricolored Bat. An adult post-lactating female was submitted from Junction City, Union county, on 5 June 2015.

Bat rabies

Between 16 June and 3 December 2015, 104 bats were received by the Arkansas Department of Health for rabies testing. Of these, 9 were damaged or decomposed leaving 95 testable samples. Species that tested negative included 20 Evening Bats (*Nycticeius humeralis* (Rafinesque)), 7 Gray Bats (*Myotis grisescens* A. H. Howell), 3 Northern Long-eared Bats (*Myotis septentrionalis* (Trouessart)), and one Silver-haired Bat (*Lasionycteris noctivagans* (Le Conte)). Rabies was detected in the following:

Eptesicus fuscus (Palisot de Beauvois). Of 38 tested Big Brown Bats, 4 rabid individuals originated from 2 counties. A rabid juvenile female was collected 16 July 2015 from Fort Smith, Sebastian County. Three rabid specimens originated from Pulaski County: one juvenile female from Little Rock collected 11 August 2015, and from North Little Rock an adult male (16 November 2015) and an adult female (22 October 2015).

Lasiurus borealis (Müller). Two of 17 Eastern Red Bats were rabid: an adult female collected 11 August 2015 from Hot Springs, Garland County, and an adult female collected 12 October 2015 from Ashdown, Little River County.

Lasiurus cinereus (Palisot de Beauvois). An adult female Hoary Bat collected 3 August 2015 from Cabot, Lonoke County, was rabid.

Perimyotis subflavus F. Cuvier. One of 4 Tricolored Bats was rabid. It was an adult female submitted 31 July 2015 from Hot Springs, Garland County.

Molossidae – Free-tailed Bats

Tadarida brasiliensis (I. Geoffroy). Three of 4 Brazilian Free-tail Bats tested positive. An adult male collected 12 August 2015 was submitted from Benton, Saline County. Two adult males from Hot Springs, Garland County, were submitted 19 August 2015 and 2 September 2015.

ORDER RODENTIA

Sciuridae– Sciurid Rodents

Marmota monax Linnaeus – Woodchuck. Carroll County: a photographic voucher of a woodchuck, found killed on the road 3 km W Osage, GPS 36.191974N, 93.444788W, was taken 20 October 2015 by MBC. Both Sealander and Heidt (1990) and Tumlison *et al*. (2007) reported that woodchucks had been seen in Carroll County, but this is the first verified record. Connior *et al*. (2011, 2013) recently reported woodchucks from nearby Marion and Searcy counties.

Muridae–Murid Rodents

Sigmodon hispidus Say and Ord – Cotton Rat. Searcy County: about 3 km S jct. AR St. Hwy 14 and Ramblewood Trail, off Ramblewood trail (36.052048°N, 92.594601°W). On 01 January 2016, MBC observed 2 adult cotton rats feeding on corn dispersed by a deer feeder. They had been fairly active around the deer feeder evidenced by the numerous runways in the close vicinity (Figure 2). Cotton rats primarily consume grasses, but are known to consume a variety of food items (Schwartz and Schwartz 2002). This is, to our knowledge, the first documented record of cotton rats consuming supplemental corn for wildlife. The direct importance of supplemental deer feed on cotton rats is unknown.

Figure 2. *Sigmodon hispidus* foraging tunnel in Searcy County.

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Characterizing Nanoparticle Size by Dynamic Light Scattering

M. Zaman[1], S. Ang[1], and S. Singh[2]

[1]*Electrical Engineering, University of Arkansas, Fayetteville, AR 72701*
[2]*Physics Department, University of Arkansas, Fayetteville, AR 72701*

Correspondence: zaman@uark.edu

Running title: Characterizing Nanoparticle Size by Dynamic Light Scattering

Abstract

The Dynamic Light Scattering (DLS) Technique was used to determine the size, shape and diffusion coefficient of rod-like nanoparticles. The intensity auto-correlation functions of light scattered by particles in a solution were measured and analyzed to obtain the relaxation rates for decay of intensity correlations. These decay rates are related to the diffusion coefficients pertaining to the motion of the particle. In the case of nanorods, there are two types of motion - translational and rotational. By disentangling the relaxation rates, corresponding to these two types of motion, the shape and size of nanoparticles were characterized. These experiments, though limited in scope, demonstrate the promise of dynamical light scattering as an inexpensive and convenient technique for characterizing regular shaped nanoparticles in a fluid medium as well as the capability of DLS to distinguish nanoparticle shapes with smaller aspect ratios.

Introduction

Nanoparticles have a wide range of applications including those in the fields of cell and molecular biology, biomedical engineering, and electronic devices. Many properties of nanoparticles change with their size and shape. There are several techniques for measuring the particle size and shape, some of which are relatively expensive and not user friendly. Here we explore Dynamic Light Scattering Technique (DLS) (Chu 1991) as a relatively inexpensive and convenient technique for determining nanoparticle size and shape in a fluid medium. We compare and contrast it with other techniques to establish its advantages and limitations relative to them. In this research we measured the size and shape of three different rod-like nanoparticle samples using DLS. Two of the samples consisted of bare gold nanorods of different sizes and the third one of nanorods of gold copper alloy ($AuCu_3$). A polystyrene nanosphere sample was used to calibrate the apparatus.

Theory

The theoretical models for light scattering by both nanosphere and nanorod particles are based on their polarizability tensor and its relation to scattered light intensity and polarization (Berne and Pecora 1976). In the case of nanospheres, only the translational motion contributes to the diffusion of nanoparticles. So the intensity of the scattered light is only related to translational diffusion. On the other hand, if the particle is a nanorod, both translational and rotational motion due to its anisotropic shape (different diameter and length) contribute to light scattering. The diffusion is then related to both translational and rotational motions and the model for light scattered by a nanorod particle involves its full polarizability tensor.

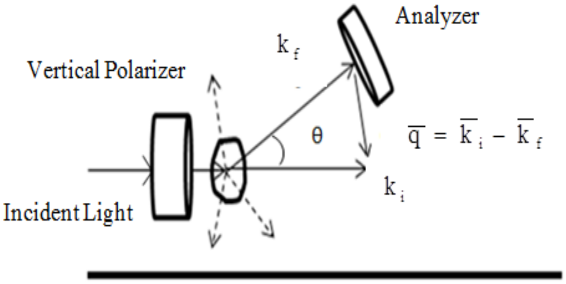

Figure 1: Light scattering geometry for a particle to be analyzed

To show the essentials of a theoretical model for diffusion of a nanorod, we consider a laser light beam illuminating a particle in a solution as shown in Figure 1. The electric field of the incident light is written as

$$\mathbf{E_i}(\mathrm{r},\mathrm{t}) = \mathbf{n_i}\mathrm{E_o} \exp \mathrm{i}(\mathbf{k_i}.\mathbf{r} - \omega_i \mathrm{t}), \qquad (1)$$

where $\mathbf{n_i}$ is the polarization of the incident light wave, E_o is the amplitude of the electric field, $\mathbf{k_i}$ is the wave vector in the direction of propagation of incident light wave and ω_i is its angular frequency. The time and position dependent scattered electric field is then given by (Chu 1991)

$$E_s(R,t) = \frac{-k_f^2 A_o}{4\pi R\varepsilon_o} \exp i\left(k_f R - \omega_i t\right)\left[\mathbf{n_f}.\left(\delta\alpha_{if}(\mathbf{q},t).\mathbf{n_i}\right)\right] \tag{2}$$

where A_o the amplitude of the scattered electric field, $\mathbf{q} = \mathbf{k_i} - \mathbf{k_f}$ is the wave vector difference between incident and scattering wave vectors, which is also called the momentum transfer wave vector. The term $\mathbf{n_f}.\left(\delta\alpha_{if}(\mathbf{q},t).\mathbf{n_i}\right)$ is the component of the molecular polarizability tensor in the direction of the initial polarization $\mathbf{n_i}$ and the final polarization $\mathbf{n_f}$. This component is denoted by $\delta\alpha_{if}(\mathbf{q},t)$.

The spectral density of scattered light can be measured from the scattered electric field through its time correlation function which is proportional to the polarizability fluctuations. The Fourier spectral density of the scattered field is proportional to

$$\mathbf{I}_{\mathbf{if}}^{\alpha}(\mathbf{q},\omega) = \frac{1}{2\pi}\int_{-\infty}^{+\infty} dt \exp i\left(\omega_f t - \omega_i t\right)\mathbf{I}_{if}^{\alpha}(\mathbf{q},t) \tag{3}$$

where $\mathbf{I}_{if}^{\alpha}(\mathbf{q},t) = \left\langle \delta\alpha_{if}^{*}(\mathbf{q},0)\delta\alpha_{if}(\mathbf{q},t)\right\rangle$,

$$\delta\alpha_{if}(\mathbf{q},t) = \sum_{j=1}^{N}\alpha_{if}^{j}(t)\exp\left(i\mathbf{q}.r(t)\right),$$

and N is the total number of particles illuminated by laser light.

If both incident light and scattered light are vertically polarized, the scattered light spectral density or autocorrelation in term of polarizability tensor depends on the molecular polarizability α_{zz}^{j}. On the other hand if incident light is vertically polarized and scattered light is horizontally polarized, the scattered light spectral density depends on molecular polarizability component α_{yz}^{j}. These two scattered light spectral density equations are given below:

$$I_{VV}^{\alpha}(\mathbf{q},\ t) = \langle N\rangle\left\langle \alpha_{zz}^{j}(t).\alpha_{zz}^{j}(0)\right\rangle \mathbf{F}_s(\mathbf{q},t) \tag{4}$$

$$I_{VH}^{\alpha}(\mathbf{q},\ t) = \langle N\rangle\left\langle \alpha_{yz}^{j}(t).\alpha_{yz}^{j}(0)\right\rangle \mathbf{F}_s(\mathbf{q},t) \tag{5}$$

where $F_s(\mathbf{q},t) = \exp\left(-q^2 D\right)$ and D is the diffusion coefficient (Einstein 1926).

In the molecule-fixed coordinate system, the above equations can be expressed in terms of second order spherical harmonics. After rotational diffusion analysis these autocorrelation functions can be finally expressed in terms of translational (Γ_{tr}) and rotational relaxation (Γ_{rot}) rates (Glidden and Muschol 2012) which are related to the corresponding diffusion coefficients D_{tr} and D_{rot} via

$$I_{VV}^{\alpha}(\mathbf{q},\ t) = A\exp\left(-\Gamma_{tr}t\right) + B\exp[-(\Gamma_{tr} + \Gamma_{rot})t], \tag{6}$$

$$I_{VH}^{\alpha}(\mathbf{q},\ t) = C\exp\left[-\left(\Gamma_{tr} + \Gamma_{rot}\right)t\right], \tag{7}$$

where $A = \langle N\rangle\alpha^2$, $B = \langle N\rangle\left(\frac{4}{45}\right)\beta^2$ $C = \langle N\rangle\left(\frac{1}{15}\right)\beta^2$,

$\Gamma_{tr} = q^2 D_{tr}$, $\Gamma_{rot} = -6D_{rot}$ and α, β are the isotropic and anisotropic parts of the polarizability tensor, respectively.

The relation between translational diffusion coefficient and length of the nanorod is (Glidden and Muschol 2012)

$$D_{tr} = \frac{k_B T}{3\pi\eta L}F(AR), \tag{8}$$

where F(AR) is a model dependent function of the aspect ratio (AR)

$$F(AR) = \ln(AR) + 0.312 + \frac{0.565}{AR} - \frac{0.1}{AR^2}. \tag{9}$$

Another relation for length of the nanorod and rotational diffusion coefficient is

$$D_{rot} = \frac{3k_B T}{\pi\eta L^3}G(AR), \tag{10}$$

where G (AR) is another model dependent function of the aspect ratio

$$G(AR) = \ln(AR) - 0.662 + \frac{0.917}{AR} - \frac{0.05}{AR^2}. \tag{11}$$

By combining these two equations, the length of nanorods can be expressed in terms of translational and rotational relaxation rate,

$$L = \frac{1}{q}\sqrt{54\frac{\Gamma_{tr}}{\Gamma_{rot}}}H(AR) \tag{12}$$

where H(AR)= G(AR)/F(AR). The value of H(AR) is approximately 0.5 for our experiment. To determine the aspect ratio of the nanorod, the length, obtained from Eq. (12) is used in the model-dependent aspect ratio function.

Method

The main part of the experimental set up is a scattering chamber mounted on a goniometer (BI-200SM) shown in Figure 2. A collimated and vertically polarized He:Ne laser beam is focused into the center of the scattering chamber that holds the scattering sample. Light scattered at 90 degrees to the direction of incident light is collected and guided to a photomultiplier tube (PMT). The output from the photomultiplier is used to measure the two-time intensity auto-correlation function of the scattered light. The analysis of the measured correlation function is carried out by the light scattering software included with the DLS instrument (Brookhaven BI-9000AT digital correlator with 9KDLSW software). A temperature controller is also included in the set up to record measurements at different temperatures by changing the sample temperature, if desired. The sample holder test tube was cleaned with isopropyl alcohol, acetone and de-ionized water. As the particles to be measured were in the nanometer range, the solvent medium was filtered by 20 nm syringe filters.

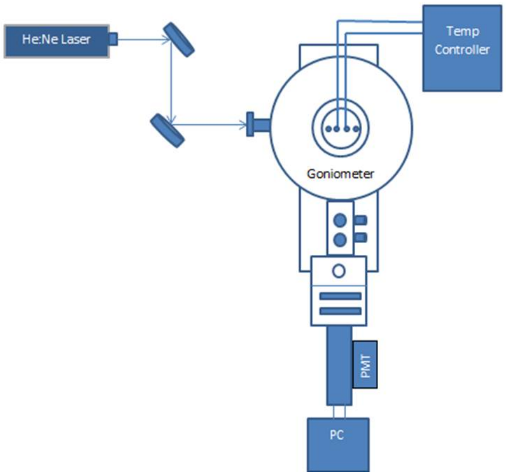

Figure 2: An outline of the experimental setup. Vertically polarized light from a laser is focused into a sample cell at the center of the goniometer. Light scattered at 90 degrees from forward direction is detected by a photomultiplier tube.

Results

The size of nanorods and nanospheres was determined by analyzing the measured correlation functions using the software package that came with the correlator. The software allows several different approaches to analyzing the data to determine particle size and shape. The cumulant data fitting method was used for nanospheres. In the case of nanorods, a double exponential fit was used to separate translational and rotational diffusion constants as these two types of motion are governed by different relaxations rates. This was reflected in the auto-correlation function of the scattered light. By using these relaxation rates and scattering wave vector, the length and diameter of the nanorods were determined using Eqs. (8) - (12).

Both polarized (VV) and depolarized (VH) light experiments were carried out for the three samples labeled as 001, RPD700D and RPD235AD. The polarized scattered light was used to obtain the size through translational and mixed relaxation rates. The mixed relaxation rate was also independently confirmed by depolarized light scattering measurements.

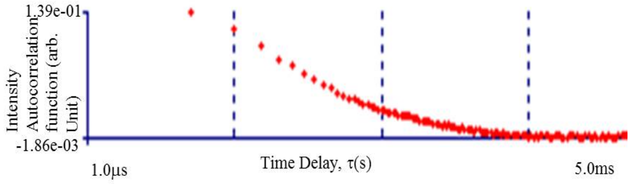

Figure 3: Autocorrelation function of vertically polarized light (VV) experiment for sample RPD235AD

The first experiment was with vertically polarized scattered light (VV). A typical experimentally measured autocorrelation for sample RPD235 is shown in Figure 3. A double exponential fitting of the measured auto-correlation function gave the relaxation rate vs relaxation rate intensity graph is sown in Fig. 4. The measured translational relaxation rate was 2.3 kHz and mixed relaxation rate was 31 kHz. The rotational relaxation rate is the (positive) difference between mixed and translational relaxation rates. So the calculated rotational relaxation rate was 28.8 kHz.

In the depolarized scattered light (VH) experiment, the relaxation rate extracted from the measurements was 29.2 KHz which was in reasonable agreement with that derived from the measurements of mixed relaxation rates in polarized light (VV) experiment. A typical intensity auto-correlations function of this experiment is shown in Figure 5.

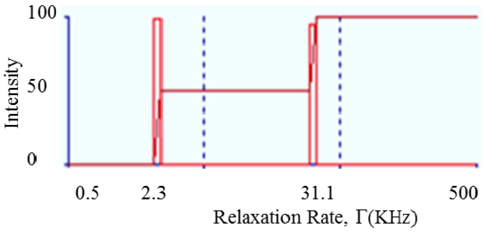

Figure 4: Relaxation rate intensity (weight) vs relaxation rate graph for sample RPD235AD

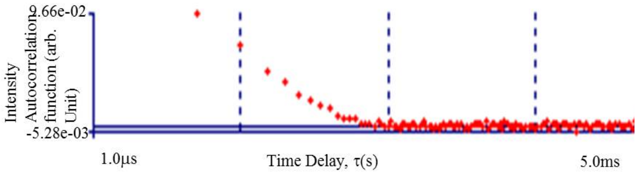

Figure 5: Typical autocorrelation function of depolarized light (VH) for sample RPD235AD

The scattering angle of the experiment was 90 degrees, refractive index of solvent (toluene) is 1.496 and incident laser light wavelength was 633nm. The calculated scattering wave vector was

$$q = \frac{4\pi\eta}{\lambda}\sin\left(\frac{\theta}{2}\right) = \frac{4\times 3.14\times 1.496}{633\text{nm}}\sin\left(\frac{90}{2}\right) = 0.021/\text{nm}$$

Finally, by using equation (12), the calculated length, L of the nanorod was 93.3nm. The aspect ratio found from the equation (10) was 4.4 which gave the diameter of the nanorod to be 21.2 nm. In this way two others sample were also characterized. Table 1 shows a comparison of length and diameter determined by dynamic light scattering technique with those obtained from transmission electron microscopy (TEM). The TEM image of sample 001 was supplied by the manufacturer (Chen et al. 2013) and the TEM images of other two samples were taken at the University of Arkansas Nanoscience Center. In the case of sample RPD007 and RPD235AD, the DLS experiment was repeated 25 times which allowed us to extract average length and diameter along with standard deviations. On the other hand, due to limited amount of sample 001, the experiment could be repeated only thrice from which only average length and diameter were obtained.

Discussion

The purpose of this research was to explore the viability of dynamic light scattering technique for determining nanorod size and shape in a fluid medium. We demonstrated the viability of the technique by successfully measuring three nanorod samples. In the case of sample RPD235AD both polarized and depolarized scattered light were intense enough to allow measurement of nanorod size and shape. For the other two smaller size samples, polarized and depolarized scattered light intensities were low because light scattering is directly proportional to the ratio of the fourth power of particle size to wavelength ratio. The particle size determination of these two samples could still be done by polarized scattered light (VV). However, the depolarized scattered light intensity was even smaller because of the smaller aspect ratio and could not be used to confirm measurements of mixed decay rate obtained from polarized light experiments for these two samples.

From Table 1, we find that our measurements have pushed the limits of DLS for size and shape determination to lower AR values than previous studies, where the same technique was used for comparatively bigger aspect ratio particles (Rodrigue-Fernandez et al. 2007). We also find that, especially for biological applications, the light scattering technique is better suited than, for example, TEM, as DLS allows measurements of nanoparticle shape and size in life-like conditions in a fluid medium.

Table 1: Comparison of DLS and TEM results

Sample Name	**Length (nm)**		**Diameter (nm)**	
	DLS	TEM	DLS	TEM
001	18.2	24 ± 4	9.2	10 ± 1
RPD700D	27 ± 8	23 ± 8	13 ± 3	10 ± 2
RPD235AD	95 ± 1	80 ± 8	32 ± 3	25 ± 3

Conclusion

The experiments described here show that dynamic light scattering is an inexpensive and effective technique for analyzing particle shapes and sizes down to a few nanometers and aspect ratios as small as 1.9 for certain types of particles. For more complicated shapes or aspect ratios close to one, it may yield only average size information. To realize the full potential of DLS and fully characterize its limitations as a technique for determining shape and size will require further studies.

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Occurrence of Shoal Chub, *Macrhybopsis hyostoma* (Cypriniformes: Cyprinidae) in Unusual Habitat in the Arkansas River System of Arkansas: Could Direct Tributaries be Refugia Allowing Persistence Despite Fragmentation of Instream Habitat?

J.A. Brown[1], H.W. Robison[2], and C.T. McAllister[3*]

[1]*USDA Forest Service, Ozark-St. Francis National Forest, Ozark, AR 72949*
[2]*Department of Biology, Southern Arkansas University, Magnolia, AR 71754-9354*
[3]*Science and Mathematics Division, Eastern Oklahoma State College, Idabel, OK 74745*

[*]Correspondence: cmcallister@se.edu

Running Title: Shoal Chub in Lake Dardanelle subbasin of AR River

The Shoal Chub, *Macrhybopsis hyostoma* (Gilbert), is one of a complex of 5 species of the genus formerly included in the *M. aestivalis* species complex, but was recognized as a distinct species by Underwood et al. (2003). This small, streamlined cyprinid fish with reduced eyes is adapted for life on the bottom of turbid, large swift rivers over sand or gravelly raceways with strong current (Moore 1950, Metcalf 1966, Reno 1969, Robison and Buchanan 1988, Luttrell et al. 1999, Eisenhour 2004). It is easily identified by small round black spots scattered over its sides and dorsum, rounded head, fleshy elongate snout, subterminal (inferior) mouth, presence of 2–4 well-developed maxillary barbels, and large pectoral fins (Page and Burr 2011). Therefore, it cannot be confused with any other Arkansas fish species. A pelagic spawning habit is also a typical life history aspect of big river cyprinids, like the Shoal Chub (Perkin and Gido 2011). In Arkansas, *M. hyostoma* is currently considered to be an imperiled (S2) species by The Nature Conservancy (NatureServe 2015).

Here, we provide a record of *M. hyostoma* from unusual habitat in the Arkansas River system, namely a small direct tributary to the Arkansas River. This finding may shed new light on the status of the species in the Arkansas River system, in particular, within the Dardanelle Reservoir sub-basin.

On 6 October 2015, JAB collected 3 specimens of *M. hyostoma* using a dip-net from a small unnamed direct tributary (Fig. 1) of the Arkansas River just S of the Ozark-Jetta Taylor Lock and Dam 12 at Ozark, Franklin County (35.46811°N, 93.81610°W). Digital images of these minnows were forwarded to HWR for positive identification and they were confirmed as *M. hyostoma*. On 15 October 2015, HWR and CTM independently visited the site and, while using a 1-man seine, collected an additional 19 specimens (43.8 ± 4.2, range 34–50 mm total length) of *M. hyostoma* for parasite studies. On 21 October 2015, JAB returned to the site and collected a series of 13 voucher specimens of *M. hyostoma*. Collectively, these specimens represent only the second time *M. hyostoma* has been taken in the Arkansas River Basin since 1963. In addition, we document the first time this species has ever been collected in a habitat outside of the mainstem Arkansas River in the state.

Figure 1. Study site showing where Shoal Chubs were collected in Franklin County. A. Google.Earth view showing Lock and Dam and study site (dot) just S of power station with Arkansas River to right. B. Tributary where specimens were collected.

The small unnamed tributary to the Arkansas River where this minnow was collected (Fig. 1B) is approximately 3.2 km long, the last 0.8 km flowing through US Army Corp of Engineer land at Aux Arc Park before the terminus at the lock. Fish collections were made about 20–30 m upstream of the confluence with the Arkansas River at the lock. Fish were collected from a 0.3–0.4 m deep riffle/run/pool complex in moderate current. Other fishes collected in the tributary included Red Shiner (*Cyprinella lutrensis*), Redfin Shiner (*Lythrurus umbratilis*), Bullhead Minnow (*Pimephales vigilax*), Green Sunfish (*Lepomis cyanellus*), Western Mosquitofish (*Gambusia affinis*) and Slough Darter (*Etheostoma gracile*). The tributary exhibits reliable flow and is typically a 0.9–1.8 m wide, relatively clear stream with a substrate of silt, sand, and small rocks (but not cobble or gravel). The depth of the stream was 0.3–1.0 m at the time the species was first discovered. This stream experiences great fluctuations in discharge throughout the year and was inundated recently in spring (Apr. 2015) by seasonal flooding (JAB, *pers. obs.*). There is relatively little bankside cover, with a powerline right of way above the reach where collections were made. Also, a small swath of woody vegetation occurs above the channel where it flows through Aux Arc Park. When discharge is high the stream deposits large amounts of sand along the banks. The senior author (JAB) has made several subsequent trips to the stream (Oct. – Dec. 2015) and has found the species to be plentiful in the reach.

The discovery of any large riverine species in a small, sandy-bottomed side tributary represents an enigma. The collection of an occasional waif fortuitously taken in a small tributary might be dismissed as slightly unusual. However, the discovery of a population inhabiting a direct tributary separate from the main river is noteworthy. Perhaps initially, individuals from the mainstem Arkansas River were pushed up and into this small tributary after seasonal flooding and have continued to reside there (without moving back into the mainstem river) over the sand, silt, and small boulder substrate provided in the stream bed. Unlike other species of *Macrhybopsis* that locate prey primarily through the use of cutaneous taste buds, Davis and Miller (1967) reported the Shoal Chub is primarily a sight feeder on the basis of patterns in brain morphology and distribution of external taste buds. In addition the eyes are much larger than in other members of the genus.

Prior to damming, the Arkansas River was characterized by very wide, shallow, and unshaded channels with sand and gravel substrates and widely fluctuating water levels, turbidity and temperature. Fragments of this type of instream habitat were left by the creation of instream structures such as dams, locks and impoundments which radically altered substrate characteristics and flows along with other habitat parameters. Subsequently, a decline in abundance and distribution of several native fishes (Cross and Moss 1987, Echelle et al. 1995) and bivalve mollusks (Distler and Bleam 1995) in large portions of the Arkansas River Basin had been shown. Luttrell et al. (1999) reported that *M. hyostoma* had disappeared from about 55% of its historic range in the Arkansas River. This decline of native fishes has been linked to reservoir construction and groundwater removal for irrigation (Luttrell et al. 1999, 2002). Large river fragments created by impoundments make upstream migrations difficult due to the broadcast drifting eggs and obligatory drifting larval stage of typical big river minnows such as the Shoal Chub (Perkin and Gido 2011)

Robison and Buchanan (1988) surmised that *M. hyostoma* was apparently extirpated from the lower mainstem of the Arkansas River in Arkansas, a 400 km reach of the river where the species was locally abundant in the 1880s. The Arkansas River from the mouth of the Verdigris River near Muskogee, Oklahoma, downstream through to its confluence with the White River in Desha County, Arkansas, was greatly modified by the McClellan-Kerr Navigation System. This includes a complex of locks and dams for barge traffic that extends from central Oklahoma to the Mississippi River. Luttrell et al (1999) stated that the last population of *M. hyostoma* from the river in Arkansas probably coincided with the 1969 completion of Ozark Lock and Dam which inundated flowing-water habitat in the vicinity of Dardanelle, Pope County. Luttrell et al (1999) lists an Oklahoma State University Collection (OSUS 7224) in 1963 from the Arkansas River at Ozark Lock and Dam. Shoal Chubs were believed extirpated or nearly so on the Arkansas River (Luttrell et al. 2002) until McAllister et al. (2012) reported the first specimens (*n* = 27, Univ. Tennessee [UT 44.9984]) in the lower Arkansas River at mile 4, at Jimmie Bend, Desha County, collected on 13 October 2003. Miller and Robison (2004, p. 128) have mapped *M. hyostoma* throughout the Arkansas River mainstem and the lower portions of its main tributaries in Oklahoma although they do note that the species has been extirpated from some of its former range.

While *M. hyostoma* in the Arkansas River is currently considered rare, it has a shorter stream length requirement threshold (instream conditions of appropriate flow and sandy/gravely substrates) to complete its life history requirements than most big river minnows (Perkin and Gido 2011). Its presence in the Mississippi River is widespread (Eisenhour 2004, N.H. Douglas *pers. comm.*). Indeed, J. Killgore (*pers.*

comm.) confirmed that *M. hyostoma* is one of the most abundant fishes collected in the lower Mississippi River along the Arkansas state border. The present specimens are believed to be only the second time *M. hyostoma* has been collected in the upper Arkansas River Basin in the state since 1963. Additional research focusing on small direct tributaries may help elucidate the actual status of populations of *M. hyostoma* within much of the Arkansas River in Arkansas.

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New Chigger (Acari) Records from Arkansas Amphibians (Caudata, Anura) and Reptiles (Sauria)

M.B. Connior[1*], C.T. McAllister[2], L.A. Durden[3], S.E. Trauth[4], and H.W. Robison[5]

[1]Life Sciences, Northwest Arkansas Community College, Bentonville, AR 72712
[2]Science and Mathematics Division, Eastern Oklahoma State College, Idabel, OK 74745
[3]Department of Biology, Georgia Southern University, Statesboro, GA 30458
[4] Department of Biological Sciences, Arkansas State University, State University, AR 72467
[5] Department of Biological Sciences, Southern Arkansas University, Magnolia, AR 71754

[*]Corresponding author: mconnior@nwacc.edu

Running Title: New Chigger Records from Arkansas Amphibians and Reptiles

Little is known about chiggers of Arkansas herpetofauna, but 2 species, *Hannemania dunni* Sambon and *Eutrombicula cinnabaris* (Ewing) have been reported from amphibians (McAllister et al. 2013 and references therein) and lizards (McAllister 1980) from that state. There are also reports of *Eutrombicula alfreddugesi* (Oudemans) from Arkansas lizards, but that species has been synonymized with *E. cinnabaris*. Here we report these 2 chiggers from 8 species of amphibians and 5 species of reptiles from Arkansas and provide a detailed summation of previously published herpetofaunal hosts of these 2 chiggers from the state.

During June 1973 and again between June 2013 and August 2015, we examined the following 5 reptiles and 8 amphibians from Calhoun, Carroll, Hempstead, Independence, Lincoln, Montgomery, Nevada, Polk, and Union counties for chiggers as follows: **AMPHIBIA: CAUDATA:** one Ouachita dusky salamander (*Desmognathus brimleyorum*), 12 Caddo Mountain salamanders (*Plethodon caddoensis*), 2 Fourche Mountain salamanders (*P. fourchensis*), and 9 Ouachita Mountain salamanders (*P. ouachitae*); **ANURA:** 29 dwarf American toads (*Anaxyrus americanus charlesmithi*), 4 bird-voiced treefrogs (*Hyla avivoca*), 63 southern leopard frogs (*Lithobates sphenocephalus utricularius*), 7 pickerel frogs (*L. palustris*); **REPTILIA: SAURIA:** one prairie lizard (*Sceloporus consobrinus*), 2 eastern collared lizards (*Crotaphytus collaris*), one prairie racerunner (*Aspidoscelis sexlineatus*), one five-lined skink (*Plestiodon fasciatus*), and one broadhead skink (*P. laticeps*). *Desmognathus conanti* from southern Arkansas is now referred to as *D. brimleyorum* (Kozak et al. 2005); therefore, the populations around Nevada and Ouachita that were previously identified as *D. conanti* are now synonymized with *D. brimleyorum*.

Chiggers were collected, preserved in 70% (v/v) ethanol, cleared in lactophenol, slide-mounted in Hoyer's medium (Walter and Krantz 2009) and identified using appropriate guides (Sanbon 1928, Loomis 1956, Brennan and Goff 1977, Loomis and Wrenn 1984). *Hannemania* chiggers were carefully removed from encapsulations on amphibian hosts using dissecting scissors and fine forceps and stored in vials of 70% ethanol until they could be cleared and slide-mounted. Chigger vouchers are deposited in the General Ectoparasite Collection in the Department of Biology at Georgia Southern University (accession nos. L3644-3645, L3647-3652, L3654-3656, L3658, L3660-3662, L 3681, L3685, L3692, L3705, L3725, L3734-3735, L3737). Host vouchers are deposited in the Arkansas State University Museum, Herpetological Collection (ASUMZ), State University, Arkansas or the Henderson State University Museum, Herpetological Collection (HSU), Arkadelphia, Arkansas.

We collected chiggers from a total of 13 species of amphibians and reptiles (Table 1). The following species were infested with *H. dunni*: *D. brimleyorum* (Polk Co.: 3 Oct. 2013 [2 hosts]; Nevada Co.: 25 Oct. 2013 [2 hosts]); *P. caddoensis* (Montgomery Co.: 19 Oct. 2013 [3 hosts], 25 Oct. 2013 [3 hosts]); *P. fourchensis* (Polk Co.: 18 Oct. 2013 [2 hosts]); *P. ouachitae* (Polk Co.: 3 Oct. 2013 [2 hosts]; 4 Oct. 2013 [1 host]; 18 Oct. 2013 [6 hosts]); *A. a. charlesmithi* (Union Co.: 15 Oct. 2013 [1 host]); *L. palustris* (Independence Co.: 5 Apr. 2014 [2 hosts]); and *L. s. utricularius* (Union Co.: 15 Oct. 2013 [2 hosts]; 18 Feb. 2014 [14 hosts]. The following species were infested with *E. cinnabaris*: *H. avivoca* (Calhoun Co.: 22 Jul. 2014 [1 host]); *P. fasciatus* (Hempstead Co.: 21 May 2014 [individual]); *P. laticeps* (Lincoln Co.: 29 Jun. 2014 [1 host]); *A. sexlineatus* (Baxter Co.: 4

Figure 1. *Hannemania dunni* chiggers infesting a *Plethodon fourchensis* from Polk Co. Arrows indicate chiggers on the toes and leg regions. Photo by SET.

Jun. 1973 [1 host]); *S. consobrinus* (Polk Co.: 10 Jun. 2013 [1 host]); and *C. collaris* (Carroll Co.: 1 Aug. 2015 [1 host]).

Arthropoda: Acarina: Leeuwenhoekiidae *Hannemania dunni* Sambon, 1928

This chigger has been reported from a variety of amphibians, including both anurans and caudates (Walters et al. 2011). The geographic range includes the midwestern and eastern United States (Walters et al. 2011, McAllister et al. 2013), with a recent report from adjacent Union Parish, Louisiana (Connior et al. 2016). This is the most common chigger of Arkansas amphibians (Appendix). It has been previously reported in Arkansas from *D. brimleyorum*, Oklahoma salamander, *Eurycea tynerensis*, Ozark zig-zag salamander, *Plethodon angusticlavius*, *P. caddoensis*, *P. fourchensis*, Kiamichi Mountain salamander, *P. kiamichi*, *P. ouachitae*, and *L. palustris*. We report, for the first time, this chigger parasitizing *A. a. charlesmithi* and *L. s. utricularis* from Arkansas. Several authors (Brandt 1936, Loomis, 1956, Murphy 1965, Westfall et al. 2008) have also reported leopard frogs as hosts from other states.

The chigger infestation of salamanders within the Ouachita Mountains is interesting. Several endemic salamanders (*P. caddoensis*, *P. fourchensis*, *P. kiamichi*, and *P. ouachitae*) as well as *D. brimleyorum* can have high infestation rates as noted by previous studies (McAllister et al. 2002, Winter et al. 1986). These high infestations can lead to deformed limbs as seen in Fig. 2. Yet, neither western slimy salamanders (*Plethodon albagula*) nor southern red-backed salamanders (*Plethodon serratus*), which occur sympatrically with these endemic hosts, has been reported as a host of *H. dunni*. Indeed, we have examined numerous (>100) individuals from both Arkansas and Oklahoma within the Ouachita Mountains (Connior and McAllister, *unpubl. data*) and have not found a single host infested with *H. dunni*. This is also supported by previous studies of not detecting any infested *P. albagula* and/or *P. serratus* (Duncan and Highton 1979, Winter et al. 1986, McAllister et al. 1993, 2002, Anthony et al. 1994).

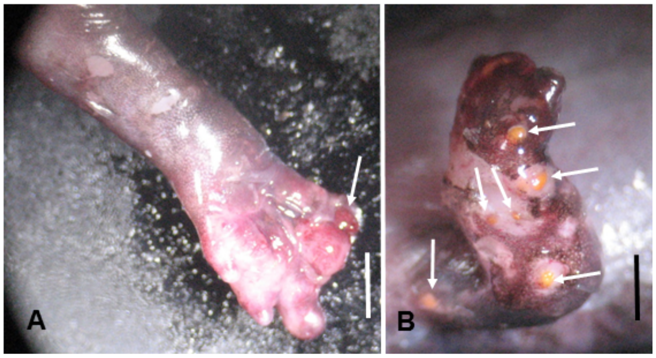

Figure 2. Chigger infestation on *Desmognathus brimleyorum*, Polk Co. A. Massive infestation showing deformed limb (stump missing digits) with encapsulated chigger (arrow). B. Another deformed limb with encapsulated chiggers (arrows). Scale bars = 5 mm. Photos by CTM.

Trombiculidae, *Eutrombicula cinnabaris* (Ewing, 1920)

This is a widely-ranging chigger that parasitizes a large variety of vertebrates including amphibians (Fig. 1) and, primarily, reptiles (both lizards [Figs. 3-4] and snakes) (Mertins et al. 2011; Walters et al. 2011). It has been previously reported on herpetofauna throughout the midwest and eastern United States, including Arkansas (Walters et al. 2011) and Texas (Mertins et al. 2011). It has been previously reported on herpetofauna throughout the midwest and eastern United States including Arkansas (Walters et al. 2011). This is the most common chigger of Arkansas reptiles (Table 1) and free-living larvae were reported from 55 Arkansas counties by Wicht and Rowland (1987). It has been previously reported in Arkansas from *S. consobrinus*, *C. collaris*, *P. fasciatus*, and *P. laticeps* (Wolfenbarger 1952, McAllister 1980). We provide additional records for the previously listed hosts, as well as *A. sexlineata*, and an amphibian, *H. avivoca*. Numerous authors (see Walters et al. 2011) have reported this chigger from the prairie racerunner. Additionally, Trauth et al. (2004) show an image of *A. sexlineata* from Arkansas infested by chiggers, presumably, *E. cinnabaris*. The bird-voiced treefrog represents a new host for *E. cinnabaris* and the first chigger reported to infest this anuran. Reports of *E. cinnabaris* from amphibians are relatively rare (Mertins et al. 2011).

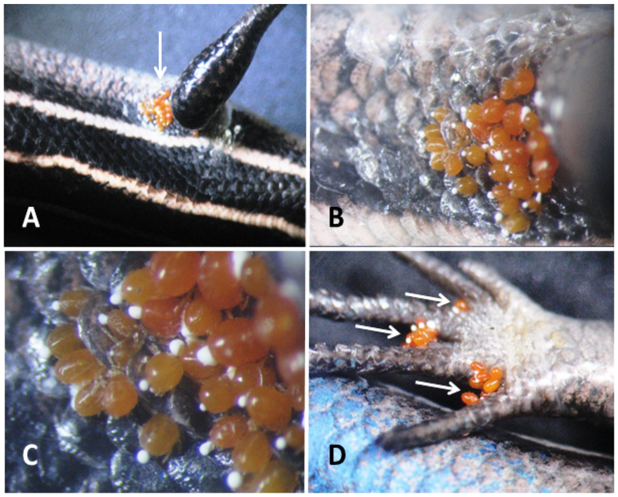

Figure 3. *Eutrombicula cinnabaris* chiggers infesting *Plestiodon fasciatus*, Hempstead County. A. chiggers on axilla (arrow). B. Close-up of chiggers on axilla. C. Aggregation of chiggers. D. Chiggers on digits (arrows). Photos by CTM.

There are at least 30 species of salamanders, 29 species or subspecies of frogs, and 13 native species and subspecies of lizards in Arkansas (Trauth et al. 2014). Although we have provided information on several species of herpetofauna infested with ectoparasitic chiggers, many species still need to be surveyed. We expect additional hosts and perhaps new distributional records will be reported with further study.

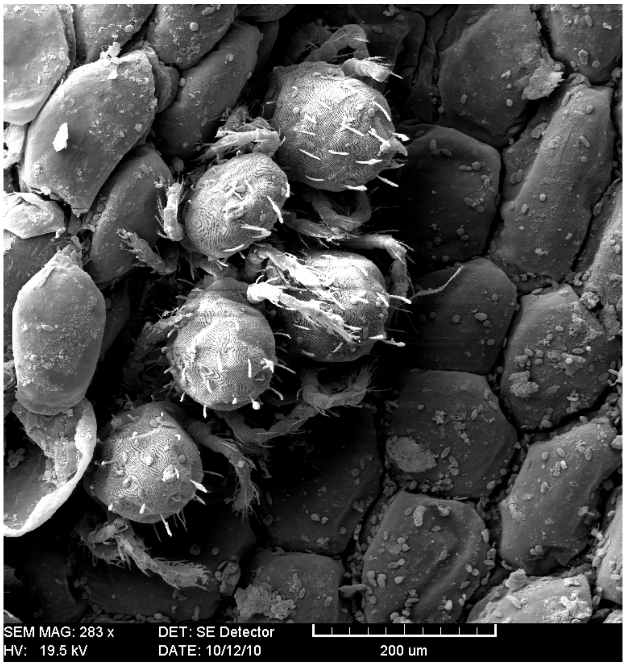

Figure 4. SEM showing *Eutrombicula cinnabaris* infesting an *Aspidoscelis sexlineatus* from Baxter County. Photo by SET.

Acknowledgments

The Arkansas Game and Fish Conservation provided scientific collecting permits to MBC, CTM and SET. We thank Drs. R. Tumlison (HSU) for expert curatorial assistance and J. O. Whitaker, Jr. (Indiana State University) for helpful comments.

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Appendix. Summary of chiggers reported from amphibians and reptiles from Arkansas.

Chigger	**Host**	**Locality (Co.)**	**Reference**
Eutrombicula cinnabaris	***Hyla avivoca***[1]	Calhoun	This study
	Aspidoscelis sexlineatus	Baxter	This study
	Crotaphytus collaris	Carroll	This study
		Izard	McAllister (1980)
	Plestiodon fasciatus	Hempstead	This study
		Izard	McAllister (1980)
	Plestiodon laticeps	Izard	McAllister (1980)
		Lincoln	This study
	Sceloporus consobrinus	Crawford, Newton	Wolfenbarger (1952)
		Izard	McAllister (1980)
Hannemania dunni	***Desmognathus brimleyorum***	Montgomery	Loomis (1956)
		Nevada	This study
		Polk	Loomis (1956); McAllister et al. (1995a); This study
		not given	Winter et al. (1986)
	Eurycea multiplicata	Conway	McAllister et al. (1995b)
	Eurycea tynerensis	Franklin	McAllister et al. (2013)
	Plethodon angusticlavius	Montgomery	This study
	Plethodon caddoensis	Polk	Anthony et al. (1994); McAllister et al. (2002); This study
		Montgomery	Crossley 1960); McAllister et al. (2002)
		not given	Winter et al. (1986)
	Plethodon fourchensis	Polk	Loomis (1956); Duncan and Highton (1979); McAllister et al. (2002); This study
		not given	Winter et al. (1986)
	Plethodon kiamichi	Polk	McAllister et al. (2002)
	Plethodon ouachitae	Polk	Loomis (1956); Duncan and Highton (1979); McAllister et al. (2002); This study
		not given	Winter et al. (1986)
	Anaxyrus americanus charlesmithi	Union	This study
	Lithobates sphenocephalus utricularius	Union	This study
	Lithobates palustris	Independence	McAllister et al. (1995c); This study

[1] New Host Record

Geographic range of the Western Harvest Mouse (*Reithrodontomys megalotis*) in Arkansas

G.R. Graves

Department of Vertebrate Zoology, MRC-116, National Museum of Natural History, Smithsonian Institution, P.O. Box 37012, Washington, D.C. 20013
Center for Macroecology, Evolution and Climate, University of Copenhagen, 2100 Copenhagen Ø, Denmark

Correspondence: gravesg@si.edu

Running Title: Western Harvest Mouse in Arkansas

The Western Harvest Mouse (*Reithrodontomys megalotis*) ranges widely in western North America from southern Mexico north to southern Canada and eastward across the Great Plains to Indiana and south in the Mississippi Valley to eastern Arkansas (Webster and Jones 1982). Knowledge of the distributional range of *R. megalotis* in Arkansas has grown incrementally since the first specimens were collected at Leachville, Mississippi County in 1951 (Sealander 1954, 1956). A truer picture of the distribution in northeastern Arkansas emerged in the 1960s and 1970s from field activities of faculty and students of Arkansas State University. By 1978, *R. megalotis* had been reported from 13 counties (Clay, Craighead, Cross, Greene, Jackson, Lawrence, Lee, Mississippi, Monroe, Phillips, Poinsett, St. Francis, Woodruff) in the Mississippi Embayment east of the White River (McDaniel et al. 1978). Specimens were subsequently reported from Randolph and Crittenden counties with a questionable occurrence west of the White River in Jefferson County (Sealander and Heidt 1990). Neither McDaniel et al. (1978) nor Sealander and Heidt (1990) mentioned specific collecting locations.

An updated annotated list of Arkansas mammals (Connior 2010) presented a much different distributional range for *R. megalotis* with records reported from Greene, Lee, and Mississippi counties in the eastern portion of the state and from Columbia and Sebastian counties in western Arkansas. However, it appears that Connior's (2010) account was based on the range map for the Eastern Harvest Mouse *(R. humulis*) in Sealander and Heidt (1990). The range of this harvest mouse was further confused by the publication of a distributional map (Connior et al. 2012) similar to that presented by Sealander and Heidt (1990), but adding Sharp County and omitting Jefferson, Monroe, and Phillips counties. The purpose of this note is to review the distribution of *R. megalotis* in Arkansas and to provide information on the sole specimen collected in Phillips County, the southernmost location for the species in the lower Mississippi Valley.

I compiled data for Arkansas specimens of *R. megalotis* from mammal collection databases at Arkansas State University Museum of Zoology (ASUMZ), University of Arkansas at Little Rock (UALR), University of Arkansas at Fayetteville (UAF), and Louisiana State University (LSUMNS). No specimens were found in the collections of the University of Arkansas at Monticello (UAM), the National Museum of Natural History (USNM) or in the other vertebrate collections indexed in VertNet http://www.vertnet.org/index.html. I approximated geographic coordinates of specimen localities with Google Earth Pro. Collecting sites within 1 km of one another were lumped.

The southernmost specimen from Arkansas (Fig. 1) was collected in Phillips County at Hudson Landing (34° 11.29' N; 91° 4.26' W) on the White River levee, about 200 m south of the pumping station on 14 March 1973 (UALR 236; ♂; collected by Gary R. Graves, catalog number 20), as compared to McDaniel et al (1978). This location lies 77 km southeast of the nearest collection site in Lee County. The trap was set in a Hispid Cotton Rat (*Sigmodon hispidus*) runway in a dense stand of grass and forbs at the edge of a blackberry (*Rubus* sp.) thicket at the base of the levee.

Figure 1. Southernmost specimen (UALR 236) of *Reithrodontomys megalotis* collected in the Mississippi Valley, obtained at Hudson Landing, Phillips County, Arkansas, on 14 March 1973.

External measurements (total length = 113 mm; tail length = 54 mm; hind foot length = 16 mm; ear length = 9 mm) and pelage color pattern of the specimen closely resemble those of *R. megalotis*, but the skull could not be located for confirmation in 2013.

In order to document the identity of the Phillips County specimen, a 307 base-pair section of the mitochondrial cytochrome b gene was sequenced from a toe sample (Appendix 1). DNA was extracted using a Qiagen DNeasy Blood & Tissue kit (Qiagen). Digestion time was extended from 24 to 48 hours due to the age and condition of the specimen. PCR and Sanger sequencing followed standard protocols and primers L14841 and H15149 (Kocher et al. 1989). Raw sequence data were cleaned and verified by eye using Sequencher 5.3 (Gene Codes Corporation, Ann Arbor, Michigan, 2014). A BLAST search in GenBank (http://blast.ncbi.nlm.nih.gov) revealed the sequence to be identical to that of *R. megalotis* (GenBank: AF108707.1), which differs by more than 10% from comparable sequences of the Fulvous Harvest Mouse (*R. fulvescens*) and *R. humulis*, both of which occur in eastern Arkansas (McDaniel, et al. 1978, Sealander and Heidt 1990).

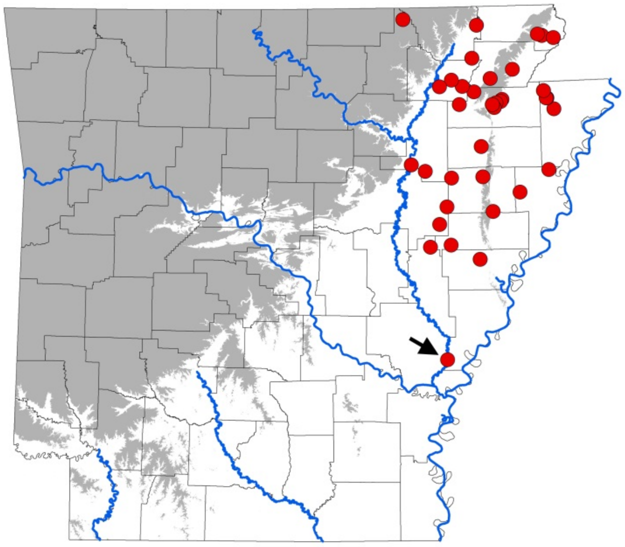

Figure 2. Distribution of vouchered specimens of *Reithrodontomys megalotis* from Arkansas. The Phillips County specimen (UALR 236) is indicated by an arrow. Gray shading represents areas >100 m above sea level. Navigable rivers are shaded in blue.

Reithrodontomys megalotis has been documented by voucher specimens from 16 counties in Arkansas (Clay, Craighead, Crittenden, Cross, Greene, Jackson, Lawrence, Lee, Mississippi, Monroe, Phillips, Poinsett, Randolph, Sharp, St. Francis, and Woodruff). All collecting sites in the Mississippi Embayment occur east of the White River (Fig. 2) at elevations ranging from 47 to 117 m above sea level. Two specimens (ASUMZ 21155, 21587) from Sharp County (2 miles south of Wirth, 248 m) are the only specimens collected thus far from the Salem Plateau in Arkansas.

Reithrodontomys megalotis, which inhabits weedy pastures, meadows, fallow fields, and fence rows (Webster and Jones 1982), has apparently spread eastward from the Great Plains to Illinois (Hoffmeister and Warnock 1955) and Indiana (Ford 1977, Leibacher and Whitaker 1998) and southward into Arkansas (Sealander 1954) coincident with the clearing of deciduous forest. McDaniel et al. (1978) found *R. megalotis* to be abundant along railroad rights-of-way in northeastern Arkansas and postulated that these provided the primary avenues for dispersal in eastern Arkansas. Elevated levees along the east bank of the White River and the west bank of the Mississippi River also provide dispersal corridors southward into flood-prone lowlands of Phillips County. In any event, *R. megalotis* had dispersed to within 27 km of the Montgomery Point Lock and Dam at the mouth of the White River by 1973. It should be noted that relatively little mammal trapping has been conducted in this area during the past 40 years. The broad channel of the Mississippi River to the east and the flooded and densely wooded corridor along the lower White River to the west may represent insurmountable natural dispersal barriers to this species of open habitat formations (Webster and Jones 1982). This hypothesis should be tested with new distributional surveys west of the lower White River.

Acknowledgements

I thank Bob Sikes (UALR) for permission to take a tissue sample from the Phillips County specimen, Tom Risch and Tracy Klotz (ASUMZ) for providing the catalog of harvest mouse specimens deposited in the Arkansas State University Museum, and Matt Connior and John Hunt (both UAM) for information on other Arkansas collections. Matt Connior and an anonymous reviewer provided helpful comments on the manuscript. I am grateful to Amy Driskell and Tripp Macdonald (Laboratory of Analytical Biology, USNM) for obtaining the cyt b sequence. I acknowledge the continuing financial support of the Alexander Wetmore Fund (Smithsonian Institution) and the Smoketree Trust.

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Appendix 1. Mitochondrial cytochrome b gene (307 bp) from a specimen of *Reithrodontomys megalotis* (UALR 236) collected at Hudson Landing, Phillips County, Arkansas on 14 March 1973.

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TTTTGGATCTTTACTAGGAATCTGCTTAGTTATCCAA
ATTTTAACAGGATTATTTCTAGCTATACATTATACAT
CAGACACATCAACAGCATTTTCATCAGTTACACACAT
TTGCCGAGACGTAAACTATGGATGATTTATCCGATAT
ATACATGCAAACGGAGCCTCTATATTTTTTATTTGCC
TTTTTCTTCATGTAGGACGAGGAATATATTATGGTTC
ATATACCTTTACAGAAACATGAAACATTGGAATCGTA
CTATTATTTGCCGTAATAGCCACAGCATTCATAGGAT
ATGTTCTTCCA
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An Adult Female Mosquito Survey in Southwest Missouri in 2014

O.E. Jamieson[1*], J.L. Moreland[2], and D.H. Jamieson[2]

[1]*1259 W. Mount Comfort Road, Apt. 203, Fayetteville, AR 72701*
[2]*Department of Biological Sciences, Crowder College - Cassville Campus, 4020 North Main Street, Cassville, MO 65625*

[*]Correspondence: oejamies@uark.edu

Running Title: An Adult Female Mosquito Survey in Southwest Missouri in 2014

In the fall of 2008 and 2009, 35 students enrolled in freshman biology courses at NorthWest Arkansas Community College participated in a landing/probing mosquito survey to determine if the Asian tiger mosquito, *Aedes albopictus* (Skuse), was the principal pest mosquito in Northwest Arkansas (Wilson and Jamieson 2010). 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. The West Nile Fever vector *Culex pipiens* (Linnaeus) was a distant second at 6.4%.

We conducted a similar survey in the summer of 2014 in Southwest Missouri. Sampling followed 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 2 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). There were 4 collection sites, one each within the city limits of Cassville (36.6800° N, 93.8694° W), Washburn (36.5894° N, 93.9639° W), Monett (36.9218° N, 93.9259° W) and Crane (36.9039° N, 93.5711° W) Missouri. Six students made a total of 42 collections beginning on June 4th and concluding on September 25th. A total of 216 specimens was collected represented by 11 species and 5 genera (Table 1). The greater numbers and diversity in Southwest Missouri is probably explained by the fact that the collection sites were located in more rural areas than in the Northwest Arkansas survey. The rural environment offers a wider array of larval development sites than does the suburban environment sampled in the Arkansas survey. The primary oviposition sites offered to mosquitoes in the suburban area are artificial containers such as discarded automobile tires, flower pots, house gutters and other habitats that resemble the tree holes which *A. albopictus* originally utilized as a larval habitat in its native region of Southeast Asia (Hawley 1988, Moore et al. 1988). Regardless, the Asian tiger mosquito dominated both surveys.

Table 1. Species Survey of Landing/Probing Mosquitoes in Southwest Missouri, 2014.

Species	**Percentage of Total**
Aedes albopictus	44.9
A. trivittatus	17.6
Culex erraticus	11.1
A. vexans	9.3
C. pipiens	8.8
C. restuans	2.8
Psorophora ferox	1.9
O. canadensis	1.4
A. triseriatus	1.4
Anopheles quadrimaculatus	0.5
P. ciliata	0.5

Aedes albopictus has colonized virtually all cities within the Ozark Mountains Physiographic Region and in many areas is locally the only pestiferous species (Jamieson and Olson 1995, Pfitzner et al. 1998). In addition, its presence and abundance is of major concern because of its ability to vector diseases such as dengue fever and chikungunya (Miller and Loaiza 2015). The concern regarding Zika virus affecting travelers returning to the United States has made the monitoring of *A. albopictus* populations even more important. The Centers for Disease Control lists both

Aedes aegypti (Linnaeus) and *A. albopictus* as the principal vectors of this potentially devastating arbovirus (CDC – Zika 2016). *A. albopictus* is easily distinguished from native species by its small size, distinctive black and white markings and stripe on the top of the thorax (scutum) (Figure 1).

Fig.1: Distinctive markings on *Aedes albopictus*

Culex pipiens (Linnaeus) was the second most abundant mosquito collected in the Northwest Arkansas study although it only represented 6.4% of the total number of specimens collected. Wilson and Jamieson (2010) mentioned its presence as significant because of its ability to vector West Nile fever (Kilpatrick et al. 2005). In this study it was slightly more abundant (8.8% of total specimens collected) but was surpassed by another *Culex* species, *Culex erraticus* (Dyar and Knab) at 11.1%. Both are competent West Nile potential vectors because of their preference for avian blood (Bolling et al. 2005). It is interesting to note that the third author has conducted surveys, both larval and adult, across the Ozarks for the last 25 years and has never encountered *C. erraticus*. The larval production site was never found in this study, but the third author has collected *C. erraticus* in rice fields in Eastern Arkansas (Jamieson et al. 1994).

It is hoped that these data will be of value to vector control specialists with the Missouri Health Department.

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Hematozoan Parasites (Apicomplexa, Kinetoplastida) of Seven Arkansas Reptiles (Testudines, Ophidia)

C.T. McAllister[1*], M.B. Connior[2], H.W. Robison[3], T.J. Fayton[4], R. Tumlison[5], and S.E. Trauth[6]

[1]Science and Mathematics Division, Eastern Oklahoma State College, Idabel, OK 74745 [2]Life Sciences, Northwest Arkansas Community College, Bentonville, AR 72712. [3]Department of Biology, Southern Arkansas University, Magnolia, AR 71754-9354
[4]Gulf Coast Research Laboratory, University of Southern Mississippi, Ocean Springs, MS 39564
[5]Department of Biology, Henderson State University, Arkadelphia, AR 71999
[6]Department of Biological Sciences, Arkansas State University, State University, AR 72467

[*]Correspondence: cmcallister@se.edu

Running Title: Hematozoans of Arkansas Reptiles

Abstract

Little is known concerning the hematozoan parasites of Arkansas reptiles. Although there are previous reports in the state of these intraerythrocytic parasites infecting various reptiles, additional research is sorely needed. Here, we attempt to augment that void by providing additional hosts infected by these apicomplexans, including the first report of a trypomastigote of a *Trypanosoma* sp. from an Arkansas turtle.

Introduction

Intraeythrocytic hematozoan parasites of the genera *Haemogregarina*, *Haemoproteus*, and *Hepatozoon* have been reported to infect various vertebrates, particularly reptiles (Telford 2009). Haemogregarines are most commonly reported from aquatic turtles with leeches serving as the only known invertebrate hosts and vectors (Telford 2009). In Arkansas, hematozoans have been reported from red-eared slider, *Trachemys scripta elegans* (McAllister and King 1980), diamondback watersnake, *Nerodia rhombifer*, western rat snake, *Pantherophis obsoletus obsoletus*, and western ribbon snake, *Thamnophis proximus proximus* (Daly et al. 1984), an alligator snapping turtle, *Macrochelys temminckii* (McAllister et al. 1995) and a common map turtle *Graptemys geographica* (McAllister et al. 2014). Here, we report new records for some hematozoans from 7 (5 turtles, 2 snakes) reptiles of the state, including photomicrographs and select measurements.

Methods

Between April 2012 and May 2015, we collected the following 31 reptiles from Benton, Calhoun, Faulkner, Desha, Independence, Lincoln, Lonoke, Montgomery, Ouachita, Perry, Pulaski, Union, and White counties and examined them for hematozoans: **Testudines** – one eastern spiny softshell, *Apalone spinifera spinifera*, one common snapping turtle (*Chelydra serpentina*), one southern painted turtle (*Chrysemys dorsalis*), 4 Mississippi mud turtles (*Kinosternon subrubrum hippocrepis*), 2 eastern cooters (*Pseudemys concinna concinna*), one razorback musk turtle (*Sternotherus carinatus*), 7 common musk turtles (*Sternotherus odoratus*); **Ophidia** – 2 western cottonmouths (*Agkistrodon piscivorus leucostoma*), one each of green watersnake (*Nerodia cyclopion cyclopion*), broad-banded watersnake (*Nerodia fasciata confluens*), *N. rhombifer*, Midland watersnake, *Nerodia sipedon pleuralis, P. o. obsoletus*, 4 eastern garter snakes, *Thamnophis sirtalis sirtalis*, and 3 *T. p. proximus*. Turtles were collected with hoop traps baited with canned sardines or other fishes and snakes were taken with tongs or hand. Specimens were overdosed with an intraperitoneal injection of sodium pentobarbital (Nembutal®). Carapace length (CL) was measured for turtles and snout-vent length (SVL) taken for snakes. The plastron was removed from turtles with a bone saw. A mid-ventral incision was made on turtles and snakes to expose their hearts. Blood was obtained from the heart using ammonium heparinized (75 mm long) capillary tubes and thin films were air-dried, fixed for 1 min in absolute methanol, stained for 20–30 min with Wright-Giemsa stain, and rinsed in neutral-buffered phosphate buffer. Slides were scanned at 100× or 400× and when infected cells were found, photographs were taken and length measurements were made on most intraerythrocytic parasites (20/form) in red blood cells (rbcs) of select reptiles using a calibrated ocular micrometer under a

1,000× oil immersion lens and are reported in micrometers as means ±1SD followed by the ranges. Parasitemia levels are number of gamonts/1,000 erythrocytes counted. Host vouchers are deposited in the Arkansas State University Museum of Zoology (ASUMZ) Herpetological Collection, State University, Arkansas. Voucher slides of hematozoans are deposited in the Harold W. Manter Laboratory of Parasitology (HWML), Lincoln, Nebraska. Most reptile taxonomy follows Uetz and Hošek (2016); however, we follow Starkey et al. (2003) who elevated *C. p. dorsalis* to full species status.

Results and Discussion

Seven (50%) of the 14 individual reptile taxa, including *C. serpentina*, *C. dorsalis*, *K. s. hippocrepis*, *P. c. concinna*, *S. odoratus*, *A. p. leucostoma* and *T. p. proximus* were found to harbor hematozoans. The following were negative: 3 *K. s. hippocrepis*, 4 *S. odoratus*, 4 *T. s. sirtalis* and one each of *A. s. spinifera*, *P. c. concinna*, *S. carinatus*, *A. p. leucostoma*, *N. c. cyclopion*, *N. f. confluens*, *N. rhombifer*, *N. s. pleuralis*, and *P. o. obsoletus*. Overall prevalence with hematozoans was 10 of 31 (32%). Parasitemia in individual reptiles ranged from <1% to 10%. An average infection revealed 1–2 gamonts infected erythrocyte/20 microscopic fields. Data are presented below in an annotated format.

Apicomplexa: Adeleorina: Haemogregarinidae

Haemogregarina sp. Danilewsky, 1885 (Fig. 1A–B)

Host: Chelydra serpentina (Linnaeus, 1758) – adult, not measured, collected 29 Jun. 2014.

Prevalence: 1 of 1 (100%).

Parasitemia: 5%.

Locality: Cane Creek Lake, Lincoln County, 33.96814°N, 94.804255°W).

Previous reports: The common snapping turtle is a widespread host of various hematozoans from specimens collected in Illinois, Iowa, Kentucky, Louisiana, Massachusetts, Nebraska, Ohio, Oklahoma, Tennessee, Texas, and Ontario, Canada (Hahn 1909, Roudabush and Coatney 1937, Edney 1949, Wang and Hopkins 1965, Marquardt 1966, Herban and Yeager 1969, Desser 1973, Acholonu 1974, Paterson and Desser 1976, McAuliffe 1977, Strohlein and Christensen 1984, Siddall and Desser 1991, 2002, Brown et al. 1994, McAllister 2015).

Specimens deposited: HWML 101969.

Remarks: Kidney-bean shaped gamonts were most often observed (Fig. 1A) as well as infected rbcs with double gamonts (Fig. 1B). These gamonts ranged from 13.5 to 15.0 (mean 14.3 ± 0.3) µm in length. The parasite nucleus is about half the size (7.0 µm) of the gamont length and is situated in a polar position. Interestingly, McAllister (2015) recently reported a *C. serpentina* from Oklahoma showing a *Haemogregarina* sp. with similar morphology.

Haemogregarina sp. Danilewsky, 1885 (Fig. 1C–E)

Host: Chrysemys dorsalis Agassiz, 1857 – adult male, 118 mm CL, collected 17 Oct. 2014.

Prevalence: 1 of 1 (100%).

Parasitemia: 2%.

Locality: Kellogg Creek, just south of Jacksonville, Pulaski County (34.850581°N, 92.142688°W).

Previous reports (in C. dorsalis and/or C. picta): Florida (Langmann 1899), Georgia (Langmann 1899), Iowa (Roudabush and Coatney 1937), Massachusetts (Hahn 1909), Michigan (DeGuisti and Batten 1951), Nebraska (McAuliffe 1977), New York (Hahn 1909), Tennessee (Edney 1949), Wisconsin (DeGuisti and Batten 1951), London Zoological Gardens (Plimmer 1912), and Ontario, Canada (Siddall and Desser 2001, 2002).

Specimens deposited: HWML 101970.

Remarks: Kidney-bean shaped gamonts were short with a length of 12.5 ± 0.5 µm. The nucleus of the parasite is compact and measures 4.3 × 3.4 µm. A few elongate banana-shaped gamonts were observed but not measured. In addition, free merozoites (Fig. 1E) were seen.

Euglenozoa: Kinetoplastida:Trypanosomatidae

Trypanosoma sp. Gruby, 1843 (Fig. 1F)

Host: Chrysemys dorsalis Agassiz, 1857 – adult male, 118 mm CL, collected 17 Oct. 2014.

Prevalence: 1 of 1 (100%).

Parasitemia: <1%.

Locality: Kellogg Creek, just S of Jacksonville, Pulaski County (34.850581°N, 92.142688°W).

Previous reports: None.

Specimens deposited: HWML 101970.

Remarks: What we believe to be a single trypomastigote of a *Trypanosoma* sp. was observed in this blood smear. Roudabush and Coatney (1937) described *Trypanosoma chrysemydis* from *Chrysemys picta* (and *C. serpentina*) from Iowa. In addition, Woo (1969) was able to infect *C. picta* (and other turtles) with *T. chrysemydis* by inoculation with crop and cecal contents of infected leeches, *Placobdella ornata* and *P. parasitica*. If confirmed, this represents the first report a trypanosome from *C. dorsalis*, and the first trypanosome documented from an Arkansas vertebrate.

Haemogregarina sp. Danilewsky, 1885 (Fig. 1G)

Host: Kinosternon subrubrum hippocrepis Gray, 1855 – adult female, 96 mm CL, collected 8 Apr. 2014.

Prevalence: 1 of 4 (25%).

Parasitemia: 5%.

Locality: Tulip Creek, off St. Hwy 7, Ouachita County (33.805019°N, 92.827807°W).

Previous reports: Louisiana (Herban and Yeager 1969), Texas (Wang and Hopkins 1965).

Specimens deposited: HWML101971.

Remarks: Small bean-shaped gamonts had length measurements of 13.0–15.0 µm, mean 14.2 ± 0.3 µm. The nucleus of the parasite is moderately-long and centrally located. In addition, free merozoites were also seen. We report a haemogregarine from an Arkansas *K. s. hippocrepis* for the first time.

Haemogregarina sp. Danilewsky, 1885 (Fig. 1H–I)

Host: Pseudemys concinna concinna (Le Conte, 1830) – adult male, 175 mm CL, collected 13 Oct. 2015.

Prevalence: 1 of 2 (50%).

Parasitemia: 3%.

Locality: South Fork of the Fourche La Fave River near Hollis, Perry County (34.8706°N, 93.109458°W).

Previous reports: Louisiana (Herban and Yeager 1969, Acholonu 1974), Illinois (Marquardt 1966), Oklahoma (McAllister 2015), Tennessee (Edney 1949), Texas (Wang and Hopkins 1965).

Specimens deposited: HWML 101972.

Remarks: Bean-shaped gamonts measuring 14.5–17.0 µm (mean 16.3 ± 0.3 µm) appeared similar to those reported by McAllister (2015) from an eastern river cooter from Oklahoma.

Haemogregarina sp. Danilewsky, 1885 (Fig. 1J)

Hosts: Sternotherus odoratus – 2 adult males, 1 adult female, 75–89 mm CL, collected 29–30 Jun. 2014.

Prevalence: 3 of 7 (43%).

Parasitemia: <1%.

Localities: Silver Lake, off St. Hwy 212, Desha County (33.973838°N, 91.436226°W); Cane Creek Lake, Lincoln County (34.091873°N, 94.739463°W).

Previous reports: Georgia (Davis and Sterrett 2011), Illinois (Marquardt 1966), Massachusetts, North Carolina (Hahn 1909).

Specimens deposited: HWML101973.

Remarks: Banana-shaped gamonts were most often observed in these common musk turtles but too few to measure.

Hepatozoidae

Hepatozoon sp. Miller, 1908 (Fig. 1K)

Host: Agkistrodon piscivorus leucostoma Troost, 1836 – adult, not measured, collected 30 Jun. 2014.

Prevalence: 1 of 2 (50%).

Parasitemia: 10%.

Locality: Cane Creek Lake, Lincoln County (34.091873°N, 94.739463°W).

Previous reports: Florida (Langmann 1899, Laveran 1902), Louisiana (Marquardt and Yeager 1967, Acholonu 1969, Herban and Yeager 1969, Lowichik and Yaeger 1987), Ohio (Zoo collection, Hull and Camin 1960), Quebec, Canada (Fantham and Porter 1954).

Specimens deposited: HWML 101974.

Remarks: Elongate long-slender gamonts with a curved tail were observed in erythrocytes of this cottonmouth. These ranged from 17.0–20.0 µm, mean 18.1 ± 0.5 µm in length.

Hepatozoon sp. Miller, 1908 (Fig. 1L)

Host: Thamnophis proximus proximus (Linnaeus, 1758) – adult male, 475 mm SVL, collected 5 Jul. 2014.

Prevalence: 1 of 3 (33%).

Parasitemia: 2%.

Locality: Spring Mill, Independence County (33.920662°N, 94.777173°W).

Previous reports: Arkansas (Daly et al. 1984), Iowa (Levine and Wacha 1983), Louisiana (Lowichik and Yaeger 1987), New York (Langmann 1899), Pennsylvania (McKinstry 1973).

Specimens deposited: HWML101975.

Remarks: Daly et al. (1984, Fig. 1) shows an elongate *Hepatozoon* gamont from *T. p. proximus* from Arkansas similar to ones observed in the ribbon snake in the present study. Our elongate gamonts had length measurements of 17.0–20.0 µm, mean 18.0 ± 0.6 µm, similar to average length of 18.2 µm reported by Daly et al. (1984). In addition, Telford et al. (2004) reported *Hepatozoon sauritus* Telford, Wozniak and Butler from garter and ribbon snakes from Florida.

The differentiation of intraerythrocytic hematozoans by morphological types has been made on 2 Arkansas turtles, *T. s. elegans* by McAllister and King (1980) and *M. temminckii* by McAllister et al. (1995) using the characteristics of shape and general morphology of the parasite, measurement of the parasite nucleus (length and width), presence or parasite nucleus (length and width), presence or absence of encapsulation, staining characteristics, and effect of the parasite on the host rbc. The latter characteristic includes hypertrophy of the host cell,

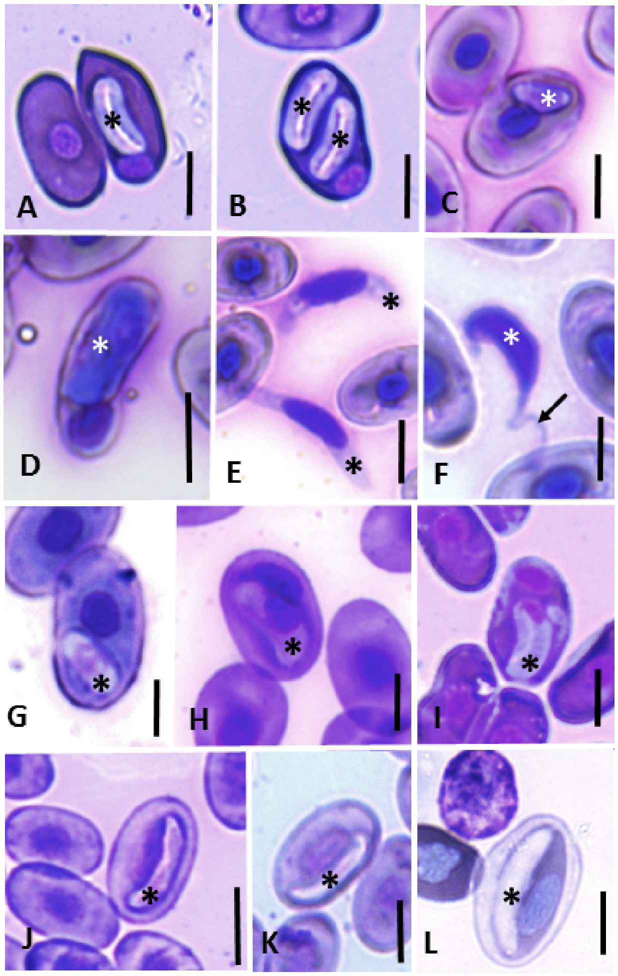

Figure 1. Hematozoan gamonts in rbcs and a possible hemoflagellate from Arkansas reptiles (designated with an *). A. Bean-shaped gamont from *C. serpentina*. B. Two gamonts in single rbc from *C. serpentina*. C. Bean-shaped gamont from *C. dorsalis*. D. Banana-shaped gamont from *C. dorsalis*. E. Two free merozoites from *C. dorsalis*. F. Trypanosome? trypomastigote (*) from *C. dorsalis*. Arrow = flagella. G. Small bean-shaped gamont from *K. s. hippocrepis*. H. Bean-gamont form from *P. concinna*. I. Another bean-shaped gamont from *P. concinna*. J. Elongate gamont from *Sternotherus odoratus*. K. Elongate curved gamont from *A. p. leucostoma*. L. Elongate gamont from *T. p. proximus*. All scale bars = 10 µm.

hemoglobin loss or displacement in the infected rbc, and change in the basic shape of the host cell. However, we consider staining a highly subjective evaluation that cannot be quantitated and would prefer to use this characteristic only in cases of obvious staining differences (see Daly et al. 1984). Using some of these criteria we were able to distinguish between 5 distinct types of hematozoan gamonts in the surveyed turtles and snakes as follows: (1) small bean-shaped, (2) large bean-shaped, (3) kidney bean-shaped, (4) banana-shaped, and (5) long elongate-shaped.

Although we document several Arkansas turtles with what we feel are *Haemogregarina* spp., we suggest caution in their placement because the taxonomic identity of these hematozoans require knowledge of their complete life cycle including developmental stages in vector and definitive host leeches (Siddall and Desser 1991, 2001) and in hematophagous invertebrates (Jacobson 2007, Smith and Desser 1997). For hemogregarines in snakes, Smith (1996) considered all to be members of the genus *Hepatozoon* even in the absence of life-cycle data to the contrary. We therefore document the 2 hematozoans from Arkansas snakes herein to represent *Hepatozoon* spp.

The results of our survey indicate that hematozoan infections of turtles and snakes are relatively common in the state. That these intraerythrocytic parasites are ubiquitous in North American reptiles is supported by the survey results of other investigators who have reported prevalence ranging from 5 to 100%. Indeed, in one study, Wang and Hopkins (1965) found 75% of 44 turtles infected with *Haemogregarina* in Texas. And in other surveys, Lowichik and Yeager (1987) showed higher prevalence (96%) in 219 *A. p. leucostoma* collected in Sarpy Swamp, Louisiana, and Acholonu (1974) reported a prevalence of 100% for haemogregarines in turtles, also from Louisiana. In own our experience, we have found certain turtles and snakes (mostly aquatic to semi-aquatic species) to be more predictably infected with hematozoans than other herpetofauna (box turtles, lizards and smaller terrestrial snakes). It is obvious that conditions favoring infectivity of reptiles with hematozoans will vary depending on several ecological factors and the natural history of any potential host.

Reptiles are hosts of numerous described and potentially undescribed hematozoans (Ernst and Ernst 1979, Telford 2009). Arkansas supports 19 species and subspecies of turtles, 13 lizards, and 45 species and subspecies of snakes (Trauth et al. 2004). We suggest that future surveys seek to include a wider diversity and larger sample size of turtle, snake, and lizard hosts.

More importantly, inclusion of molecular approaches (DNA sequences) would be particularly helpful to identify some hematozoans (Allen et al. 2011, Cook et al. 2014, Maia et al. 2014) that are known with limited morphological traits. Therefore, we suggest that molecular approaches be used to elucidate the life cycles of these hematozoans, especially considering that this could potentially allow for their specific identification. Eventually, additional new host and distributional records should be found, including the possibility of discovering new species.

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Report on an Oomycete Infection (Heterokontophyta: Oomycota) in Northern Studfish, *Fundulus catenatus* (Fundulidae) from Tenmile Creek, Saline County, Arkansas

C.T. McAllister[1] and H.W. Robison[2]

[1]*Science and Mathematics Division, Eastern Oklahoma State College, Idabel, OK 74745*
[2]*Department of Biology, Southern Arkansas University, Magnolia, AR 71754-9354*

[1]Correspondence: cmcallister@se.edu

Running Title: Oomycete Infection in *Fundulus catenatus*

Cases of oomycete (water mold) infestations in fishes are relatively common (Schäperclaus 1986). Indeed, among recent emerging infectious diseases responsible for severe population declines in fish taxa, fungal and oomycete microbes have emerged as significant contributors (Gozlen et al. 2014). In addition, the oomycetes negatively impact a wide array of other taxa including insects, zooplankton, nematodes, crayfish and amphibians (Phillips et al. 2008, Beakes et al. 2012; Sarowar et al. 2014). We are not aware of any previous reports of an oomycete infection in native fishes of Arkansas. Here, we document a noteworthy oomycete infestation in Northern Studfish, *Fundulus catenatus* Storer from central Arkansas.

Fourteen adult *F. catenatus* (mean ± 1SD total length [TL] 69.9 ± 7.6, range 62-93 mm) were collected with a backpack electrofisher on 15 November 2015 from Tenmile Creek off US 70, vicinity of Lonsdale, Saline County (34.545463ºN, 92.753702ºW). Specimens were placed in creek water and taken to the laboratory within 24 hr for processing. Fish were killed by immersion in a concentrated chloretone solution and measured for TL. Two (14%) of the *F. catenatus* (70 and 76 mm) were noted of having a moderate growth of what appeared to be unknown white cotton wool-like patches on a small part of their body (head and chin) (Fig. 1). This growth was sampled by removing a portion with fine forceps, placed on a microscopic slide, stained with bromphenol cotton blue, and mounted with a coverslip. The slide was examined under a light microscope and photomicrographs were obtained. Voucher specimens of *F. catenatus* are deposited in the Henderson State University (HSU) collection, Arkadelphia.

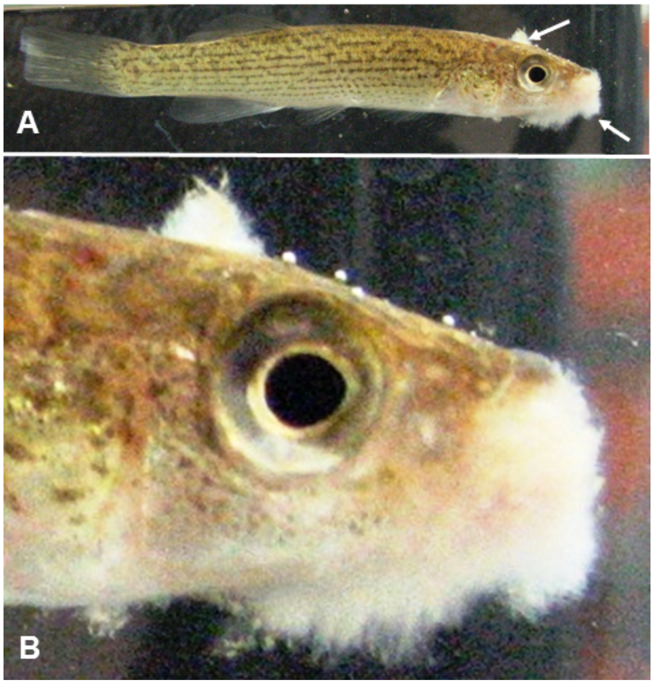

Figure 1. Infected *Fundulus catenatus* (TL = 76 mm). A. Oomycete growth (arrows) on top of head, mouth and chin. Note that there appears to be no other growth on remainder of body. B. Close-up of same showing filamentous mycelia growing on the mouth and underside of chin with smaller colonies on top of head.

Although it was not possible with confidence to determine with certainty which genus is present in this case without culturing and DNA sequence data, microscopic examination of the infestation revealed non-septate, multinucleate and unbranched or branched hyphae (Fig. 2) similar to those of the water mold (Oomycetes) Saprolegniales species (Webster and Weber 2007). The best-studied fish pathogenic oomycetes belong to this order including the genera *Achlya*, *Aphanomyces* and *Saprolegnia*. Organisms in this order reproduce asexually by releasing biflagellated spores formed in apical slightly swollen sporangia (Schäperclaus 1986, fig. 236).

Numerous other fishes collected on the same date at the Tenmile Creek site did not harbor any similar infestation, including *Campostoma spadiceum*, *Gambusia affinis*, *Lepomis cyanellus* and *Noturus* *lachneri*. In addition, we have, over the last 40+ yr, collected many fishes from all river drainages in the state and never recall seeing such a similar infection on a single fish. Therefore, we suggest this is a fairly rare event and it does not appear to pose a serious risk as a potential pathogen on Arkansas fish populations.

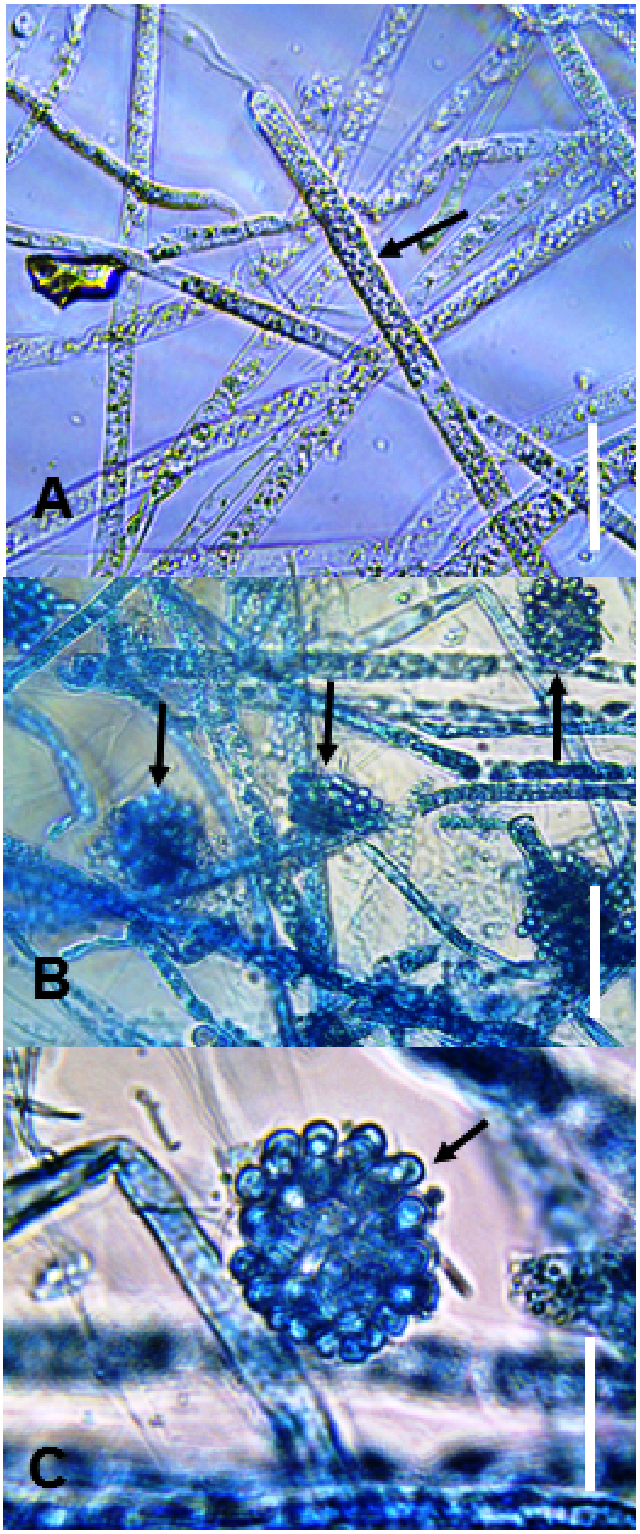

Figure 2. Oomycete infection in *Fundulus catenatus*. A. Unstained non-septate hyphae (arrow); scale bar = 50 µm. B. Three balls of encysted zoospores (arrows); scale bar = 50 µm. C. Single zoospore ball (arrow); scale bar = 25 µm. B & C stained with bromphenol cotton blue.

We document the first report of an oomycete infection in a native Arkansas fish species. Additional research on this topic, including molecular studies, will surely extend our knowledge and further hosts could be discovered having similar infestations in the state.

Acknowledgments

The Arkansas Game and Fish Commission issued a scientific collecting permit to CTM. We thank Dr. R. Gozlen (IRD, Paris, France) for information on oomycete infections in fish, Dr. R. Tumlison (HSU) for expert curatorial assistance, and the McAllister clan for help in collecting at Tenmile Creek.

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An *Epistylus* sp. (Ciliophora: Peritrichia: Epistylididae) Infestation on Green Sunfish, *Lepomis cyanellus* (Perciformes: Centrarchidae), from Arkansas

C.T. McAllister[1*], H.W. Robison[2] and S.E. Trauth[3]

[1]*Science and Mathematics Division, Eastern Oklahoma State College, Idabel, OK 74745*
[2]*Department of Biology, Southern Arkansas University, Magnolia, AR 71754-9354*
3Department of Biological Sciences, Arkansas State University, State University, AR 72467

[*]Correspondence: cmcallister@se.edu

Running Title: *Epistylis* sp. on *Lepomis cyanellus* in Arkansas

Ciliates of the genus *Epistylus* Ehrenberg, 1830 are sessile peritrichous organisms often present as a branching colony with a short oral disc and collar, and non-contractile rigid stalk (Dias et al. 2006). There are about 120 described species that generally live in freshwater environments (Lynn 2008). Epistylids are not considered true parasites but are common on crayfishes (Vogelbein and Thune 1988), the carapace of turtles (Bishop and Jahn 1941, Bovee 1976) and on the eggs, skin and gills of fishes where they may contribute to mortality from partial smothering or secondary infection (Fischthal 1949, Reichenbach-Klinke 1973, Esch et al. 1976, Miller and Chapman 1976, Crites 1977, Hazen et al. 1978, Hoffman 1999). However, some historically considered these ciliates epibionts, which colonize the surface of live substrates and serve a commensal ecological role (Wahl 1989, Fernandez-Leborans et al. 2006). Lewis et al. (1978) reported *Epistylis* on 16 of 32 fishes examined in 2 North Carolina reservoirs, mainly from centrarchids, ictalurids, and moronids. Ictalurids and salmonids seem to be especially susceptible to infestation (Hubert and Warner 1975, Hoffman 1999). Epistylids use the host as an attachment substrate, so it can feed on bacteria and suspended particles in water.

Little is known about these ciliates on Arkansas fishes. Foissner et al. (1985) reported an epizootic of *Heteropolaria colisarum* Foissner and Shubert, 1977 on the scales and fins of cultured Green Sunfish (*Lepomis cyanellus*) from the Fish Farming Experimental Station, Stuttgart, Arkansas County. Interestingly, this infection was also shown in photos on the front cover of the second edition of Hoffman's (1999) classic, *Parasites of North American Freshwater Fishes*. Lom and Dykovà (1992) have synonymized *H. colisarum* with *Epistylis.* However, to our knowledge, nothing has been published on this ciliate in native fishes from natural waters in the state. Here, we present a case of *Epistylis* sp. on *L. cyanellus* with light microscopy and scanning electron microscopy (SEM) of the infestation.

On 14 October 2015, an adult (195 mm total length) *L. cyanellus* was collected with a backpack electroshocker from the South Fork of Fourche La Fave River at Hollis, Perry County (34.8706°N, 93.109458°W). As this specimen was noted to be unusual in possessing scales and spines on the dorsal fin with some unidentified whitish growth (Fig. 1), the fish was photographed alive. No growth was noted on the gills. The specimen was immediately overdosed by immersion in tricaine methanesulfonate and several scales were removed and placed in individual vials containing 70–95% (v/v) DNA grade ethanol and 10% neutral buffered formalin (NBF). The fish was preserved in 10% formalin and later transferred to 70% (v/v) ethanol. On return to the laboratory, scrapings were taken with fine forceps from scales originally placed in ethanol. Specimens were stained with Gomori trichrome, dehydrated in 95–100% (v/v) ethanol, cleared with xylene, mounted with Canada balsam and examined using light microscopy. Photomicrographs of stereoscopic samples were taken with Canon Powershot S3IS camera fitted with a Martin Microscope adaptor (Martin Microscope, Easley, SC). Photomicrographs for light microscopy were taken with a Swift M10 Series microscope fitted with a digital camera mount. For SEM, we transferred scales and liquid suspensions in 10% NBF through a graded series of increasing ethanol solutions (70–100%). Specimens were then extracted from vials with a pipette and placed onto segments of glass coverslips (18 × 4 mm) previously coated with poly-L-lysine. An Autosamdri®–815 critical point drier (Tousimis Research Corporation, Rockville, MD; 31°C, 1072 psi, ventilation rate ~100 psi/min) was used to remove excess ethanol from cells. Dehydrated specimens on coverslips were then adhered to rectangular copper transfer boats (25 × 5 mm) with double-sided tape and

Figure 1. *Lepomis cyanellus* with whitish growth on dorsal fin and scales. Scale bar = 50 mm. Photo by Uland Thomas.

mounted onto sticky-tabbed 12 mm aluminum pin stubs. Copper boats and stubs were then coated with gold using a Cressington 108 sputter coater (Cressington Scientific Instruments Ltd, Watford, UK). Specimens examined for SEM were generated at the Arkansas Nano & Bio Materials Characterization Facility (UA-Fayetteville). A host voucher specimen was deposited in the Henderson State University Collection (HSU), Arkadelphia, Arkansas; a voucher slide of the infestation was deposited in the Harold W. Manter Laboratory of Parasitology (HWML), Lincoln, Nebraska as HWML 101962.

The unusual growth on scales of *L. cyanellus* (Fig. 1) was identified as an *Epistylis* sp. Examination of colonies using stereoscopic and light microscopy (Fig. 2) revealed colonies comprising a various number of individuals, with a branched and smooth, noncontractile stalk and fully expanded zooids. When examined by SEM (Fig. 3), apical views of contracted zooids were prominent, and cilia could be seen atop them. The macronucleus is typically horseshoe shaped and transversely oriented in the middle-adoral region of the cell.

Fischthal (1949) reported an *Epistylis* sp. from a darter in a Wisconsin stream, and Rogers (1971) found it on pond fishes in the southeastern United States. Cloutman (1975) reported an *Epistylis* sp. on White Bass (*Morone chrysops*) and Striped Bass (*Morone saxatilis*) in North and South Carolina. In addition, Crites (1977) found *Epistylis niagarae* Kellicott on Smallmouth Bass, *Micropterus dolomieu*, Rock Bass, *Ambloplites rupestris* and Freshwater Drum, *Aplodinotus grunniens* from Ohio.

Other fishes (*n* = 28) collected on the same date and locality did not possess *Epistylis* as follows: 5 Greenside Darters (*Etheostoma blennioides*), 1 Western Creek Chubsucker (*Erimyzon claviformis*), 8 Slender Madtoms (*Noturus exilis*), 1 Logperch (*Percina caprodes*), 6 Longnose Darters (*Percina nasuta*), 4 Blackspotted Topminnows (*Fundulus olivaceus*), and 3 Wedgespot Shiners (*Notropis greenei*). In addition, we have examined over 100 *L. cyanellus* from various watersheds in Arkansas over the last decade and never have noticed any with this growth.

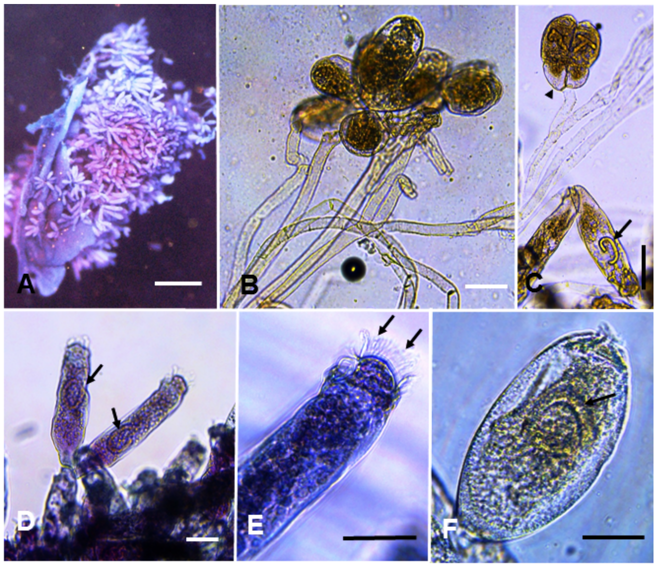

Figure 2. Light microscopy of *Epistylis* sp. from *Lepomis cyanellus*. A. Colonies from skin scraping, stereoscopic view; trichrome stain. B. Branched colonies showing group of zooids on noncontractile stalks; unstained. C. Zooids showing macronucleus (arrow) and daughter cells from binary fission (arrowhead); unstained. D. Two zooids showing macronuclei (arrows); trichrome stain. E. Single elongate zooid showing cilia (arrows); trichrome stain. F. Single vase-shaped zooid showing macronucleus (arrow); unstained. Scale bars: A = 200 µm; B–F = 50 µm.

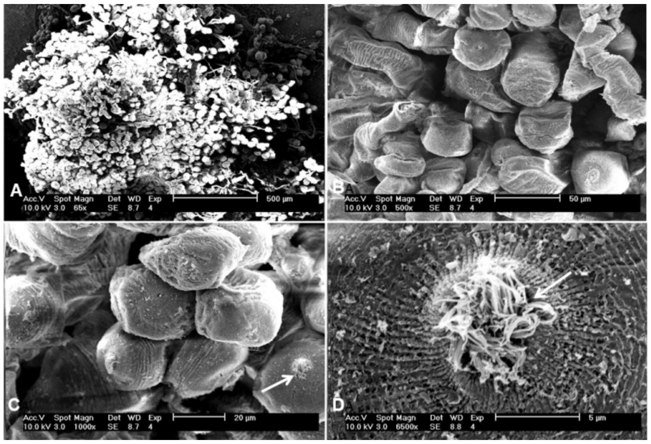

Figure 3. Scanning electron micrographs of *Epistylis* sp. on scales of *Lepomis cyanellus*. A. Low magnification showing colonies on single scale. Bar = 500 µm. B. Higher magnification of apical view of contracted zooids. Bar = 50 µm. C. Another apical view showing cilia on one colony (arrow). Bar = 20 µm. D. Close-up showing cilia (arrow). Bar = 5 µm.

In summary, we provide the initial report of an *Epistylis* sp. from a non-cultured *L. cyanellus* and the first time SEM photomicrographs of this form have been documented. Future studies should include molecular analyses (18S rRNA sequences) to help further provide an identity of this species.

Acknowledgments

We thank Dr. C.M. Whipps (SUNY-ESF) for help in identification of *Epistylis* sp., U. Thomas (Chicago, IL) for Fig. 1, Drs. M. Benamara and B. Martin (Arkansas Nano & Bio Materials Characterization Facility, UA-Fayetteville) for technical assistance with SEM, and S.L. Gardner (HWML) and R. Tumlison (HSU) for expert curatorial assistance. The Arkansas Game and Fish Commission issued Scientific Collecting Permits to CTM and HWR.

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Gastrointestinal Parasites of the Northern River Otter, *Lontra canadensis* (Carnivora: Mustelidae), from Arkansas

C.T. McAllister[1*], A. Surf[2], R. Tumlison[2], C.R. Bursey[3], and T.J. Fayton[4]

[1]*Science and Mathematics Division, Eastern Oklahoma State College, Idabel, OK 74745,* [2]*Department of Biology, Henderson State University, Arkadelphia, AR 71999,* [3]*Department of Biology, Pennsylvania State University-Shenango, Sharon, PA 68421*
[4] *Gulf Coast Research Laboratory, University of Southern Mississippi, Ocean Springs, MS 39564*

*Correspondence: cmcallister@se.edu

Running Title: Helminths of River Otter from Arkansas

The northern river otter, *Lontra canadensis* (Schreber) ranges from Alaska and most of Canada south to northern California and northern Utah in the west and from Newfoundland southward to Florida in the east (Reid 2006). In Arkansas, *L. canadensis* is found statewide in rivers, creeks, bayous, and lakes bordered by timber (Sealander and Heidt 1990). The river otter primarily feeds on fish, but will also consume aquatic invertebrates, amphibians, reptiles, birds, and other mammals (Tumlison et al. 1986, Larivière and Walton 1998, Melquist et al. 2003, Ligon and Reasor 2007).

The river otter has been a common subject of several surveys on its helminth parasites. These previous studies were conducted on specimens from 15 US states, including Alabama, Alaska, Arkansas, Florida, Georgia, Louisiana, Maryland, Massachusetts, Michigan, Montana, New York, North Carolina, Oklahoma, Oregon, and Tennessee, and Newfoundland and Ontario, Canada (summarized by Fleming et al. 1977, Stuht 1978, Shoop and Corkum 1981, Tumlison et al. 1984, Addison et al. 1988, Snyder et al. 1989, Forrester 1992, Hoberg et al. 1997, Kollars et al. 1997, Kimber and Kollias 2000, Feldhamer et al. 2003, Dronen 2009, Crait et al. 2015, McAllister and Fayton 2015). Although it appears the helminth fauna of *L. canadensis* is fairly well known, there are obvious gaps in our knowledge, particularly for populations in Arkansas. Indeed, only a single nematode parasite has been reported from river otters from Arkansas (Tumlison et al. 1986). Here, we report more detailed information on a survey of gastrointestinal helminth parasites of *L. canadensis* from the state.

During the 2013–2015 fur trapping seasons, 38 adult river otter carcasses (21 males, 17 females) were obtained from licensed fur buyers in Arkansas (*n* = 2), Clark (*n* = 1), Crawford (*n* = 5) , Franklin (*n* = 2), Lonoke (*n* = 1), Pike (*n* = 4), Polk (*n* = 5), Perry (*n* = 1), Prairie (*n* = 9), Pulaski (*n* = 1), Scott (*n* = 1), St. Francis (*n* = 1), Sebastian (*n* = 2), Union (*n* = 1), White (*n* = 1) and Yell (*n* = 1) counties (Fig. 1). Most of the carcasses were obtained frozen, but many had remained at ambient temperatures for 24 hrs or more before being frozen. These conditions may have limited the diversity of parasites we were able to locate. After thawing, a mid-ventral incision was made to expose the gastrointestinal tract, which was split lengthwise from the esophagus to anus and its contents rinsed into a sieve then examined for helminths. Several 15 cm segments of tissue were cut and placed in Petri dishes and their contents rinsed in 0.9% w/v saline. Trematodes were removed from the stomach and upper small intestine, transferred to 70% v/v ethanol, stained in acetocarmine or Ehrlich's hematoxylin, cleared in methyl salicylate and mounted in Canada balsam. Nematodes and acanthocephalans originally fixed in 70% v/v ethanol were examined as temporary mounts in glycerol. Host voucher specimens (skulls only) were deposited in the Henderson State University Collection, Arkadelphia, as HSU 719, 763, 784, 809, 867, 870; parasite vouchers were deposited in the Harold W. Manter Laboratory of

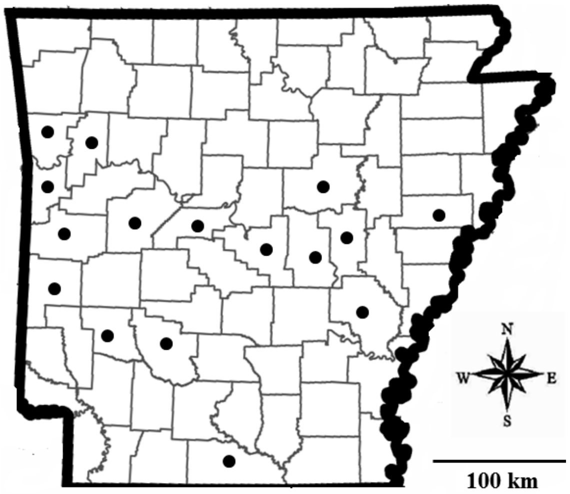

Fig. 1. Sixteen counties in Arkansas where river otters were collected.

Parasitology (HWML), University of Nebraska, Lincoln, NE.

A total of 37 of 38 (97%) of the *L. canadensis* harbored at least 1 helminth; 1 (3%) of the river otters from Polk County harbored a multiple infection of 2 helminths. Two specimens positive for the nematode, *Dracunculus insignis* (Leidy, 1858) will be reported elsewhere by RT. An annotated list of the parasites found follows:

Trematoda: Digenea: Echinostomatidae, *Bashkirovitrema canadense* Dronen, 2009

Twenty-four of 38 (63%) of the river otters were found to be infected with *B. canadense* (HWML 94121) in the gastrointestinal tract; the mean intensity was 8.4 ± 18.2, range 1–61 worms. Dronen (2009) erected *B. canadense* to accommodate specimens of *Bashkirovitrema* Skrjabin, 1944 harvested from the intestine of mustelids, including *L. canadensis* and the American mink, *Neovison vision* (Schreber), from Florida, Georgia, Louisiana, New York, North Carolina, and Ontario, Canada (Dronen 2009) and found this species to be morphologically most similar to *Bashkirovitrema incrassatum* (Diesing, 1850), which parasitizes the Neotropical otter, *Lontra longicaudis* (Olfers, 1818), in Brazil, South America. Recently, McAllister et al. (2015) reported *B. canadensis* from Oklahoma; we report this species from Arkansas for the first time.

Strigeidida: Clinostomatidae, *Clinostomum* sp.

Seven *Clinostomum* sp. (HWML 94120) were found in the stomach of a single (3%) *L. canadensis* collected on 16 February 2015 from the Little Missouri River, Clark County. This parasite (yellow grub) is typically found in the metacercarial stage in fishes and amphibians with fish-eating birds (herons, egrets) serving as definitive hosts (McAllister et al. 2010). In the current case, this parasite is considered an incidental finding of a host which has a piscivorous diet. However, this is the first time *Clinostomum* sp. has been reported from a river otter.

Nematoda: Dioctophymatoidea: Dioctophymatidae, *Dioctophyma renale* (Goeze, 1782)

Twelve of 38 (32%) of *L. canadensis* from Crawford, Franklin, Pike, Polk, Prairie, Pulaski, Sebastian, St. Francis and Yell counties harbored larval and pre-adults of this nematode (HWML 94122) in the large intestine; the mean intensity was 3.8 ± 9.0, range 1–31 worms. This cosmopolitan nematode, often referred to as the giant kidney worm has been found encapsulated in fishes; larvae can be transmitted along the food chain of paratenic hosts (Karmanova 1961). It is possible that American bullfrogs (*Lithobates catesbeianus*) become infected with *D. renale* by eating infected frogs of different species (Mace and Anderson 1975). Definitive hosts are carnivorous mammals, notably mink, wolves, coyotes, foxes, dogs, raccoons, and weasels. *Dioctophyma renale* has been previously reported from Arkansas (Hallberg 1953) and from *L. canadensis* from unknown localities (Kimber et al. 2000). However, we report *D. renale* in river otters from Arkansas for the first time.

Acanthocephala gen sp. (unknown genus)

Three female acanthocephalans (HWML 94123) were found in the large intestine of 3 of 38 (8%) river otters collected in February 2014, 2 hosts from Prairie and 1 host from Scott counties. As with the *Clinostomum* sp. found herein, this is considered to be an incidental finding of river otter food habits. Other acanthocephalans, also considered incidental findings, have been previously reported in *L. canadensis* from Alabama, Alaska, Florida, Oregon, Tennessee, Wyoming and Newfoundland, Canada (Schmidt 1969, Smith and Threlfall 1973, Fleming et al. 1977, Forrester 1992, Hoberg et al. 1997, Kollars et al. 1997, Crait et al. 2015).

In summary, we document a low parasite species richness as well a new distributional record for a trematode parasite of *L. canadensis* in Arkansas. The parasite list for river otters is much more extensive (see Kimber and Kollias 2000 for summary). Therefore, in order to further increase our knowledge of its parasites in the state, we suggest future surveys to include examination of fresh material, their major visceral organs, and specimens from other counties of the state, particularly northern Arkansas.

Acknowledgments

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A New Host Record for the Bat Bug, *Cimex adjunctus* (Insecta: Hemiptera) from Eastern Small-footed Myotis, *Myotis leibii* (Chiroptera: Vespertilionidae)

D.B. Sasse[1*], C.T. McAllister[2], and L.A. Durden[3]

[1]*Arkansas Game and Fish Commission, Mayflower, AR 72106*
[2]*Science and Mathematics Division, Eastern Oklahoma State College, Idabel, OK 74745*
[3]*Department of Biology, Georgia Southern University, Statesboro, GA 30458*

*Correspondence: blake.sasse@agfc.ar.gov

Running Title: New Host Record for *Cimex adjunctus*

The eastern small-footed myotis, *Myotis leibii* (Audubon and Bachman) is one of the rarest North American bats (Best and Jennings 1997). It occurs from Ontario, Canada to New England south to Georgia and Alabama and west into eastern Oklahoma (Reid 2006). In Arkansas, *M. leibii* occurs in scattered locales in the Ozarks and the western Ouachita Mountains (Sasse et al. 2013). It is ranked S1 (critically imperiled) in Arkansas by NatureServe (2016).

Little is known about the ectoparasites of *M. leibii*. As far as we can determine, only 2 species of chiggers, including *Euschongastia hamiltoni* Brennan and *Trombicula myotis* Ewing, have been reported infesting *M. leibii* from New York and Tennessee, respectively (Brennan 1947, Neuhauser 1971).

On 24 August 2015, the senior author (DBS) collected an adult female *M. leibii* from a crevice between sections of concrete guardrails on a bridge over Interstate 49 in Washington County at 35.81908°N 94.19147°W. It was found to have a single female bat bug on its left wing (Fig. 1A). The specimen was collected and shipped to CTM who identified it as belonging to the genus *Cimex*. It was subsequently placed in a vial of 70% ethanol and forwarded to LAD for specific identification.

The single adult bat bug was identified as *Cimex adjunctus* Barber using keys in Usinger (1966). A small amount of blood was present in the midgut of the specimen. The voucher specimen is deposited in the General Ectoparasite Collection in the Department of Biology at Georgia Southern University as L3726.

The senior author captured and examined small-footed bats in similar roosts in the Ozarks 461 times from 2013–2015 and associated bat bugs were only observed on two other occasions – a male bat captured at a bridge in Madison County on 28 August 2014 and a female bat captured in the same bridge on 5 September 2014, each had one *Cimex sp.*, which was not identified to species, on their left wings.

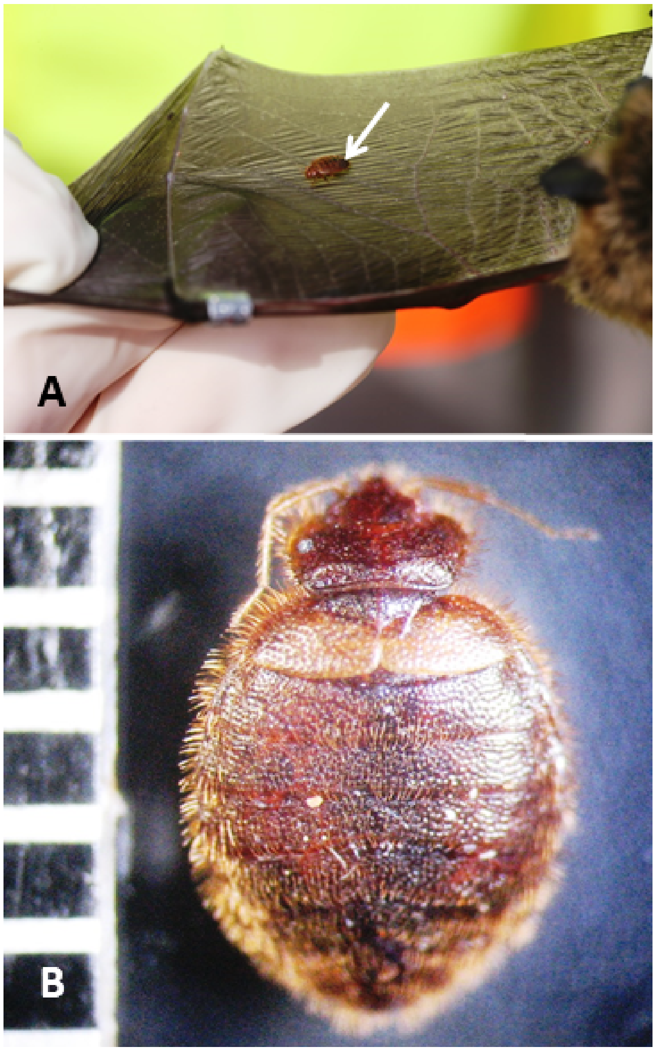

Figure 1. *Cimex adjunctus* from *Myotis leibii*. A. Bat bug (arrow) on wing. B. Stereoscopic view of *C. adjunctus*. Each scale bar on B = 1 mm.

This bug has been previously reported from at least 11 bat species ranging in southeastern Canada and eastern United States, to as far west as Colorado

(Usinger 1966, Bowles et al. 2013, Grilliot et al. 2014). In Arkansas and Texas, *C. adjunctus* was recently reported by Grilliot et al. (2014) from Rafinesque's big-eared bats, *Corynorhinus rafinesquii*.

Cimex adjunctus is common on big brown bats, *Eptesicus fuscus*, (Bowles et al. 2013) which were occasionally captured in similar roost sites on bridges used by small-footed bats. On 16 September 2015, a male big brown bat was captured in between sections of concrete guardrails in a bridge over the White River in Madison County at 35.82828°N 93.8324°W and 2 *C. adjunctus* were collected from under the right wing and one from the top of the left wing and one was seen on top of the left wing and two additional specimens were found under the right wing of a female big brown bat captured at the same location. Specimens from the male bat were sent to CTM and LAD for identification and represent the first record of this parasite on big brown bats in Arkansas (voucher specimen L3729).

Interestingly, earlier reports of bat bugs on Arkansas bats were of the closely related species *C. pilosellus* Horvath (see Price et al. 1982, Steward et al. 1986). We document *C. adjunctus* in Arkansas for the second time and provide a new host record from *M. leibii*. This marks the first record of a bat bug parasitizing *M. leibii*.

Acknowledgments

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First Record of the Opossum Shrimp, *Mysis diluviana* (Crustacea: Mysida) From Arkansas

K. Schanke[1], H.W. Robison[2], N.J. Wentz[1], and C.T. McAllister[3*]

[1]*Arkansas Department of Environmental Quality, North Little Rock, AR 72118*
[2]*Department of Biology, Southern Arkansas University, Magnolia, AR 71754-9354*
[3]*Science and Mathematics Division, Eastern Oklahoma State College, Idabel, OK 74745*

[*]Correspondence: cmcallister@se.edu

Running Title: *Mysis diluviana* in Arkansas

Opossum shrimps are tiny aquatic crustaceans (Crustacea, Malacostraca, Mysida) which superficially resemble true shrimps. The mysid species of the North American Great Lakes, formerly identified as *Mysis relicta*, has been renamed *Mysis diluviana* Audzijonyte and Väinölä based on molecular studies (Väinölä et al. 1994, Audzijonytë and Väinölä 2005, Dooh et al. 2006). These works separated *M. relicta* into 4 separate species and collectively these species are now referred to as the *M. relicta* species group. *Mysis diluviana* inhabits continental freshwater lakes of the once-glaciated northern North America, including the Great Lakes (Audzijonytë and Väinölä 2005). The purpose of this note is to provide the first documentation of *M. diluviana* in Arkansas with voucher specimens deposited in a museum repository.

Between 13–16 November 2012, 32 specimens of opossum shrimps were collected from the lower Cache River at the Monroe/Prairie County line (34.581364°N, 93.883678°W), by NW using a D-frame aquatic dip net (Appendix). All specimens were initially sent to HWR for identification. Following a tentative identification of *M. diluviana*, 2 specimens were forwarded to the Curator of Crustaceans, Dr. C.A. Taylor, Illinois Natural History Survey (INHS), Champaign, Illinois, for verification of the original identification and deposition in the INHS Crustacean Collection. Dr. Taylor confirmed the identity of specimens as *M. diluviana*. The remaining 30 opossum shrimp are currently in the personal collection of KS.

Description

Opossum shrimps are quite small (12–14 mm), with stalked compound eyes, and a single carapace covering the head and thorax without completely masking the underlying parts (Fitzpatrick 1983). The carapace is not attached posteriorly as it is in decapod crustaceans (crabs, lobsters, shrimps and crayfishes). Thoracic appendages in these shrimps are thin and biramous, and only the first 2 are maxillipeds. Males may be distinguished by having a modified fourth pleopod, the exopod of which is very long, while in females, the last 2 pairs of periopods have flattened, lamellar, ventrally projecting endites, called oostegites. The oostegites form a marsupium in which the eggs are incubated thus giving the group its name, opossum shrimps. Each of the 4 species of the *M. relicta* group has distinct genetic and morphological characteristics and morphological features such as length and shape of the setae can also be examined to identify them. They are not easily confused with 2 other freshwater shrimps inhabiting Arkansas (see Robison and McAllister 2011), *Paleomonetes kadiakensis* or *Macrobrachium ohione*, both much larger than opossum shrimps.

Geographic Distribution

Mysis diluviana inhabits continental freshwater lakes of the once-glaciated northern North America, including the Great Lakes and other deep coldwater lakes across Canada and in northern parts of the United States, including those in Wisconsin and New York (Dadswell 1974, Pennak 1989, Audzijonyte and Väinölä 2005). The species has been termed a glacial relict since it inhabits areas covered by ice sheets during the last glacial period.

Introductions

Mysis diluviana has been introduced to lakes outside its native range as a forage base for fishes, including Lake Tahoe in California and Nevada and Kootenay Lake in British Columbia, Canada (Clemens et al. 1939, Sparrow 1964). Additional stockings were made at 5 Montana lakes upstream of Flathead Lake (Bosworth 2011), and in many other lakes of the western USA and Canada (Spencer et al. 1999). A single *M. diluviana* was collected from Lake Demopolis, Alabama in 2004 (Foster et al. 2015). Opossum shrimps have also been previously reported from adjacent coastal Louisiana and Texas (Fitzpatrick 1983, Porter et al. 2008). However, they have not been previously documented from Arkansas (Bouchard and Robison, 1980, Robison and McAllister, 2011) despite numerous intensive aquatic macroinvertebrate surveys in the state by Cather and Harp (1975), Harp and Harp (1980), Farris and Harp (1982), Guntharp and Harp (1982), Higgins and Harp (1983), Cochran and Harp (1990), Chordas et al., (1996), Harp and Robison (2006), and over 45 yrs of personal collecting in Arkansas by Dr. G.L. Harp (Arkansas State University [ASU]) and HWR.

Ecology

Mysis diluviana is typically found in deep, cold oligotrophic lakes with high levels of dissolved oxygen where it occurs mainly below the thermocline, however, it has also been reported from brackish and estuarine waters (Dadswell 1974, Pennak 1989). It opportunistically feeds on zooplankton when abundant but when scarce, it will feed on phytoplankton, suspended organic debris, or from the surface of benthic organic deposits (Pennak 1989, Anderson 2010). They live for just 2 yr and become sexually mature at 12–14 mm. Breeding takes place in the winter with adults carrying young in a brood pouch until fully developed in spring (Pennak 1989).

Helminth Parasites

Opossum shrimps have been reported to harbor procercoids of the cestode, *Cyathocephalus truncatus* Pallas (Amin 1978), nematodes, *Cystidicola stigmatura* (Leidy) (Smith and Lankester 1979), an echinorhynchid acanthocephalan cystacanth (Wolff 1984), and *Echinorhynchus leidyi* (Van Cleave) (Prychitko and Nero 1983). Although we did not examine our *M. diluviana* for endoparasites, this information suggests that these shrimp can serve as intermediate hosts of a suite of parasites and could potentially introduce them into Arkansas.

Significance

Within its native range *M. diluviana* has been shown to be an important prey item for freshwater fishes (Nesler and Bergersen 1991). However, when introduced into what was considered to be an "empty" niche, its impact on the aquatic community is significant. Dramatic changes and species extinctions of native zooplankton communities have been attributed to the opportunistic feeding habits of *M. diluviana*. This change in the primary consumer composition has led to drastic ecosystem shifts in Flathead Lake, Montana (Spencer et al. 1999). The smaller opossum shrimp replaced larger native species but were unable to keep up with the growth of algae in the Lake. Furthermore, the benthic tendencies of this species provided a massive new food source for bottom dwelling lake trout, allowing the trout to increase their population and overtake kokanee (non-anadromous form of sockeye salmon) as top predator in Flathead Lake (Bosworth 2011).

Study Sites in Arkansas

The lower Cache River at the Monroe/Prairie County line (Fig. 1) is characterized by 2 different channel types. The upper portion of the lower Cache River above the Bayou DeView confluence remains sinuous and only altered by levees and channelization in the extreme headwaters. The Cache River below the Bayou DeView confluence is channelized to the confluence with the White River near Clarendon (~11 km). However, The Nature Conservancy and partners are working to restore and reconnect previously disconnected backwaters. Overall, both portions of the Cache River are best described as highly turbid, deltaic systems. Aquatic habitat of the study area was predominantly sand with small clay aggregates forming gravel like substrate. At all 4 of our collection sites (Appendix), aquatic vegetation was sparse with large woody debris being the primary instream structure.

It is obvious that *M. diluviana* is not a native member of the Arkansas aquatic fauna but why have they eluded capture previously or are they from a more

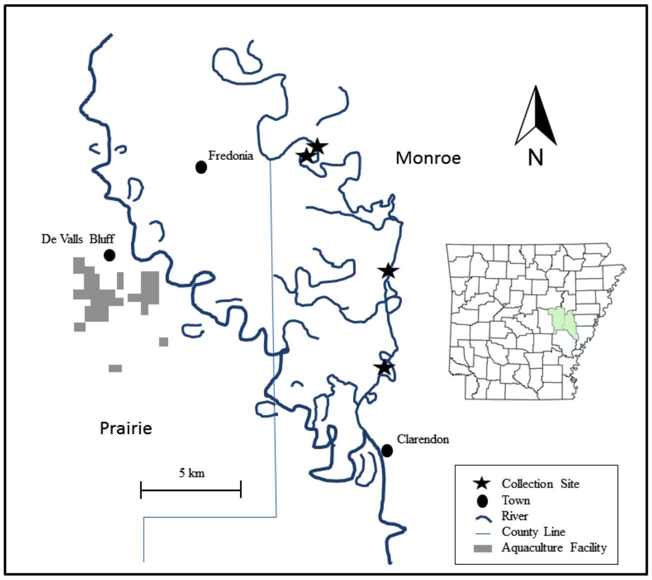

Figure 1. Four collection locations (stars) of *Mysis diluviana* in the Cache River, Monroe County, Arkansas.

recent introduction? In 2014, a re-sampling of this area took place; however, the water was much lower and the original sites could not be accessed so only snags (dead and down woody debris in the form of stumps, root wads, bark, and limbs >3cm in circumference) were sampled. No additional specimens of *M. diluviana* were taken.

Since these *M. diluviana* individuals do represent an introduction, where did they come from? Several possibilities exist. The first is that *M. diluviana* escaped from barge traffic in the area. The sample location in Monroe County is physically close to the port of Clarendon on the White River. Clarendon is the last stop for most barge traffic heading up the White River and is at the confluence of the Cache River approximately 3.5 river km downstream of the lowest observation. Given the movement of goods between the Great Lakes and Mississippi River basin, a barge may have released ballast water with *M. diluviana* individuals. A second possibility is that one of the large aquaculture facilities that culture baitfish (Golden Shiner, *Notemigonus crysoleucas*) located 11 km W of our localities may have introduced the *Mysis* specimens into the White River near the confluence of the Cache River. The 2 rivers become broadly connected in late fall and winter when the bottomlands flood (NJW and KS, *pers. obs*.). Since the areas were sampled in mid-winter, the temperatures would have been low enough to sustain *M. diluviana*.

In summary, our collection represents the first documentation of the Order Mysida in Arkansas, and specifically, the first report of *M. diluviana* in the state. Future sampling is planned at the same areas where the opossum shrimps were previously taken as well as checking in watersheds in adjoining Prairie County.

Acknowledgments

We thank Dr. C.A. Taylor (INHS) for verifying the identity of opossum shrimp, helpful comments, and expert curatorial assistance. We also acknowledge Dr. G.L. Harp (ASU) for discussions on the aquatic macroinvertebrate fauna of Arkansas through the years and his generous provision of shrimp records from the aquatic collections housed at ASU.

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APPENDIX. Four locations of 32 specimens of *Mysis diluviana* collected by N. Wentz in Arkansas (locality [latitude/longitude in decimal degrees], date of collection and number of specimens).

MONROE/PRAIRIE CO. LINE (Cache River, just S of US 70 bridge, E of Biscoe)

1. (34.77°N, 91.31°W). 13 Nov. 2012. 1.
2. (34.824°N, 91.345°W). 16 Nov. 2012. 9.
3. (34.819°N, 91.351°W). 16 Nov. 2012. 1.
4. (34.726°N, 91.316°W). 16 Nov. 2012. 21.

Unusual Concentration of Summer Tanagers (*Piranga rubra*) in Northwestern Arkansas during Winter 2015-2016

K.G. Smith*, J.C. Neal, and M. Mlodinow

Department of Biological Sciences, University of Arkansas, Fayetteville, AR 72701

*Correspondence: kgsmith@uark.edu

Running head: Unusual Concentration of Summer Tanagers

Summer Tanagers (*Piranga rubra*) typically breed in the southern United States and winter in Central and South America (Robinson 2012). They are common in Arkansas as migrants and nest during summer throughout the state (James and Neal 1986). However, winter records are few, particularly in the northern parts of the state (Arkansas Audubon Society 2015). Occasionally birds do occur in the United States in winter, particularly in Florida and along the Gulf Coast, but rarely further inland and then usually only as single birds (Robinson 2012). Formerly known as the "bee bird" (e.g. Attwater 1892, Golsan and Holt 1914), Summer Tanagers are bee and wasp specialists (Robinson 2012).

Prior to winter of 1981-1982, there were no records of wintering tanagers in northwestern Arkansas (Benton and Washington counties). Since then there have been only 9 records of Summer Tanagers in winter in northwestern Arkansas (J. C. Neal, *unpubl. data*). Almost all of these have been in female or juvenile male plumage, which cannot be distinguished in the field. Two birds remained long enough that they began molting into male plumage (J. C. Neal, *pers. observ.*), so some birds were juvenile males. Almost all birds were seen at suet feeders in Fayetteville. Only one bird was usually observed in each case, except in winter of 2003-2004 when an adult male and female-like plumage bird were found at one feeder and a juvenile male appeared at another. It was presumably that bird which returned the next 4 years to the same feeder as an adult male.

During December of 2015 and January of 2016, an unprecedented 12 reports of Summer Tanagers were made in northwestern Arkansas (Table 1). Birds were not observed during the month of November in northwestern Arkansas (M. Mlodinow, *pers. observ.*), nor were there any reports of tanagers north of there that month in eBird (Cornell Laboratory of Ornithology), suggesting that these birds arrived after fall migration would have ended in late October (James

Table 1. Summary of the 12 sightings of Summer Tanagers during winter of 2015-2016 in northwest Arkansas.

LOCATION	**FIRST SIGHTED**	**DETAILS**	**DURATION**
Rogers-Prairie Creek	4 December	visiting water feature twice	1 week apart
Fayetteville	19 December	suet feeder at least until mid-January Eating bees at hive	~24 days, off and on
Cave Springs	19 December	observed while birding	1 day, birding
Fayetteville	20 December	observed with wasp in its bill	1 day, birding
Fayetteville	22 December	observed while birding	1 day, birding
Bella Vista	31 December	regularly at suet feeder; last date 20 February	~50 days, regular visits to suet
Fayetteville	11 January	visited suet feeder until 19 January	8 days, visited regularly
Fayetteville	15 January	at suet feeder	1 day
Fayetteville	early January	found dead in yard 20 January	~20 days
Fayetteville	14 January	single observation	1 day
Fayetteville	late January	visiting suet feeder at least until February 9	~10 days +
Fayetteville	1 February	irregular visits to suet, at least until February 10	2 sightings 10 days apart

Figure 1. Summer Tanager eating a honeybee at a bee hive in Fayetteville on 12 January 2016. Note bee on the bird's left leg. Photograph by D. Steinkraus.

Figure 2. Summer Tanager eating a wasp (probably an ichneumonid) in December of 2015 in Fayetteville. Photograph by J. Neal.

and Neal 1986). Most were in Fayetteville (Washington County), but 3 birds were in Benton County at Rogers/Prairie Creek, Cave Springs, and Bella Vista.

Most of the birds were associated with suet feeders, but 3 were observed by bird watchers away from feeders (Table 1). One bird fed on bees at a hive (Fig. 1) and one bird was observed eating a wasp during December (Fig. 2). To our knowledge, no other Summer Tanagers were reported in Arkansas that winter.

What could have caused this winter season concentration of Summer Tanagers in northwestern Arkansas? First, it was a very mild winter, with no snow and abnormally high temperatures (L'Heureux 2016). Secondly, strong winds blew from the south for much of the month of November and December (NOAA 2015), so that birds may have moved north with wind assistance. Also, suet feeders could have contributed to the survival of the tanagers as most were associated with them. However, it remains a mystery why only Summer Tanagers appeared with no other unusual species.

Acknowledgments

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A Case of an Ant Head (*Crematogaster* sp.) Embedded within the Skin of a Green Treefrog (*Hyla cinerea*) from Northeastern Arkansas

C.S. Thigpen*and S.E. Trauth

[1]*Department of Biological Sciences, Arkansas State University P.O. Box 599, State University, AR 72467*

*Correspondence: christopher.thigpen@smail.astate.edu

Running Title: An Ant Head Embedded in the Skin of a Green Treefrog

A female green treefrog, *Hyla cinerea*, was collected on July 1 1989 from Poinsett County, Arkansas, 5 km north of Bay Village on Highway 163. The frog was euthanized, measured (snout-vent length = 55 mm), fixed in 10% neutral buffered formalin, and deposited into the Arkansas State University Herpetological Museum (ASUMZ 13380) in 70% v/v ethanol. During routine museum maintenance, a dark protuberance was noticed on the frog's left carpal area and, upon further inspection, was determined to be the head of an ant (Fig. 1).

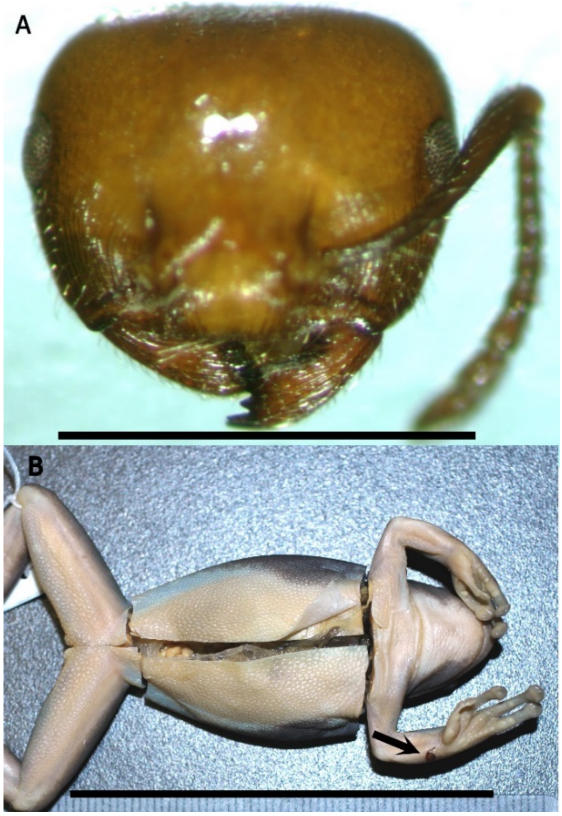

Figure 1. Ant head (A) attached to frog (arrow in B). Top scale = 1 mm, bottom scale = 55 mm.

The ant was identified as a member of the *Crematogaster* genus using Borror and Delong's Introduction to the Study of Insects (Tripplehorn and Johnson 2005) and an online identification key from Mississippi State University (MacGown 2003), but species could not be identified without the body. At the site of attachment, skin appeared to have healed around the mandibles of the ant. This would suggest the ant had been attached for some time, but exact time of attachment could not be determined. Literature on the subject is lacking and it would appear that this is one of, if not the first, published cases of a prey item remaining attached to a frog after foraging.

Acknowledgments

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

R. Tumlison[1], H.W. Robison[2], and T. L. Tumlison[3]

[1]*Department of Biology, Henderson State University, Arkadelphia, AR, 71999*
[2]*9717 Wild Mountain Drive, Sherwood, AR 72120*
[3]*367 Mt. Zion Rd., Arkadelphia, AR 71923*

[1]Correspondence: tumlison@hsu.edu

Running Title: New Records of Invertebrates from Arkansas

Because invertebrate biologists are few and scattered in Arkansas, the invertebrate fauna of much of the state is poorly known. The lack of expertise in identifying invertebrate species, coupled with a lack of seasonal collecting, have limited the publication of information regarding species occurrence and basic biology.

Herein we document new or previously unreported records of distribution and provide notes on the natural history of selected invertebrates from Arkansas. Southwestern Arkansas lies almost entirely within the West Gulf Coastal Plain natural division (Foti 1974), whereas eastern Arkansas is comprised of the Mississippi Alluvial Plain and northern Arkansas is formed largely of 2 major highland areas – the Ouachitas and Ozarks. This diversity of habitats allows for an interesting diversity of invertebrate life.

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%v/v or 90%v/v isopropanol and housed at HSU, SAU, Brigham Young University (BYU), or the United States National Museum (USNM). Digital photography also was used to document species within their habitats (images available from RT).

CLASS TURBELLARIA

Bipalium kewense Moseley 1878 – land planarian. This land planarian is easily identified by its diagnostic spade-like head and bi-colored body. In Arkansas, this planarian species was reported previously by Daly and Darlington (1981) from Pulaski (Little Rock), Faulkner (Conway), and Ouachita (Camden) counties. Tumlison and Robison (2010) provided additional records of *B. kewense* from Clark and Columbia counties in southern Arkansas.

Although native to tropical Asia, land planarians have been dispersed via the trade in tropical plants, thus they commonly are observed in greenhouses in the soil of potted plants and have become established across the southern United States (Ducey et al. 2007). Daly and Darlington (1981) 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.

On 14 May 2011, one 10 cm specimen of *B. kewense* was collected from a sidewalk in Russellville, Pope Co., AR by D. N. Miller. This represents a new county record for Pope County.

In addition, a single 8 cm long specimen of *B. kewense* was collected by HWR on 7 April 2014 from the fish research labs area of UAPB in Pine Bluff, Jefferson Co., AR, which also is a new county record.

CLASS CRUSTACEA

Crayfishes in North America are properly identified best by evaluation of secondary sexual characteristics, and especially the morphology of the first pleopods (= gonopods) of the form I male (Hobbs 1972). Form I is capable of breeding but form II is sexually nonfunctional. Ovigerous females are those bearing eggs. In the following accounts of crayfishes, the forms examined are noted. Distances given with locality data are shown as originally recorded with metric conversions in parentheses.

Cambarellus (Pandicambarus) puer Hobbs 1945 - Swamp Dwarf Crayfish. This tiny crayfish can be distinguished from its congener, *C. shufeldtii*, by the male gonopod. In *C. puer* the processes of the gonopod are curved whereas they are straight in *C. shufeldtii.* Specimens were collected by use of an aquatic dip net in vegetated backwater regions of a stream. Ovigerous females listed below are the first reports of ovigerous *Cambarellus puer* from Arkansas and were collected from April to July (26 Apr 1976, 23 May 1975, 26 July 1976, 28 July1941).

Collections: *Calhoun Co.*: Champagnolle Creek, 1 mi. (1.6 km) E of Hampton Oil Field; 25 May 1975; S. Pelt; USNM 147715 (1 ovigerous female). *Cleveland Co.*: stream under U.S. Hwy 79, 3 mi. (4.8 km) NE of junction with AR St. Hwy 15; Aug 1960; J. Bohlke; USNM 116031 (1 male I, 3 male II, 7 females). *Columbia Co.*: Bayou Dorcheat at U.S. Hwy 82, W of Magnolia, AR; 11 October 2015; HWR (2 females). *Greene Co.*: small stream 4.9 mi. (7.9 km) NE of Paragould on AR St. Hwy 1; 28 July1941; H. H. Hobbs, Jr.; USNM 117744 (6 male I, 1 female ovigerous). *Howard Co.*: ditch 12.3 mi. (19.8 km) S of Lockesburg, AR on U.S. Hwy 71; 31 July 1941; H. H. Hobbs, Jr.; USNM 117743 (3 male juveniles, 5 female juveniles). *Jackson Co.*: Village Creek at AR St. Hwy 37, E of Tuckerman, AR; 26 July 1976; R. W. Bouchard (1 male II, 3 females, 1 ovigerous female). This marks the first documentation of an ovigerous female in Arkansas.

Lafayette Co.: tributary to Bodcaw Creek about 3.5 mi. (5.6 km) from jct. of AR St. Hwy 29 and Sunray Road, on latter; 26 April 1976; R. W. Bouchard; USNM 176846 (3 male I, 1 female ovigerous). *Monroe Co.*: stream under AR St. Hwy 17, 9 mi. (14.5 km) S of jct. with U.S. Hwy 70; 17 August 1960; J. Bohlke; USNM 116035 (1). *Union Co.*: tributary to Bodcaw Bayou ca. 3.5 mi. (5.6 km) from jct. of AR St. Hwy 29 and Sunray Road on latter; 11 Jun 1981; D. Cummings; USNM 177606 (2 male II, 1 female). *White Co.*: Ditch near Bayou Des Arc, 6 mi. (9.7 km) NE of McRae, AR on U.S. Hwy 67; 14 August 1960; J. Bohlke; USNM 116030 (4 male II, 1 female).

Cambarellus (Dirigicambarus) shufeldtii (Faxon) 1884 - Cajun Dwarf Crayfish. *Cambarellus* species are the only crayfishes in Arkansas to have well-developed lateral rostral spines. Species may be distinguished using the processes of the male gonopod. Ovigerous females listed below represent the first reports of ovigerous *Cambarellus shufeldtii* from Arkansas and were collected from April to October (14 April 1973, 7 May 1982, and 11 October 2015).

Collections: *Columbia Co.*: Bayou Dorcheat at U.S. Hwy 82, W of Magnolia, AR; 11 October 2015; HWR; (2 male II; 1 ovigerous female). The ovigerous female had 29 eggs and was 1.8 cm in length.

Jackson Co.: Village Creek at AR St. Hwy 37 E of Tuckerman, AR; 19 February 1977; R. W. Bouchard (1 female). *Lafayette Co.*: unnamed oxbow lake of the Red River, 0.6 mi. (1.0 km) SW of Boyd, AR; 7 May 1982; HWR; USNM 208635 (3 male I, 2 male II, 3 females ovigerous, 3 other females). *Lawrence Co.*: Village Creek at Minturn, AR; 19 February 1977; R. W. Bouchard (1 female). *White Co.*: slough 14.4 mi. (23.2 km) W of Augusta, AR; 8 September 1948; L. Williams; USNM 132713 (1). *Woodruff Co.*: roadside ditch and culvert on U.S. Hwy 64, 2 mi. (3.2 km) W of jct. of U.S. Hwy 64 and AR St. Hwy 39, Fair Oaks, AR; 14 April 1973; H. H. Hobbs, Jr.; USNM 144583 (18 male I, 1 male II, 1 female adult, 4 female ovigerous, 4 female juvenile).

Cambarus (Lacunicambarus) diogenes Girard 1852 - Devil Crawfish. This crayfish is a primary burrower and burrows are known as deep as 6 feet (1.8 m) (Walls 2009). Specimens were dug from deep burrows along the creek.

Collections: *Lawrence Co.*: Village Creek at Minturn, AR; 19 February 1977; R. W. Bouchard (1 male I, 1 female, 3 female juveniles). This is the first record from Lawrence Co. of this crayfish species.

Cambarus (Lacunicambarus) ludovicianus Faxon 1885 - Painted Devil Crayfish. Although a primary burrower, this species occasionally leaves the protection of the burrow and seeks open water. Burrowers are always difficult to document, therefore collection and identification of a first form male is noteworthy. The male form II specimen taken was collected by use of an aquatic dip net.

Collections: *Lafayette-Columbia Co.*: Bayou Dorcheat at U.S. Hwy 82 W of Magnolia, AR; 11 October 2015; HWR; (1 male II). *Columbia Co.*: burrow in roadside ditch 3.6 mi. (5.8 km) W of Magnolia, AR on U.S. Hwy 82; 26 January 1993; HWR (1 female ovigerous). This is the first report of an ovigerous female of *C. ludovicianus* from Arkansas.

Orconectes palmeri (Faxon) 1884 - Gray Speckled Crayfish. Three poorly defined subspecies of *Orconectes palmeri* are known (Penn 1957). Only 2 occur in Arkansas. The northeastern subspecies, named the Gray-speckled Painted Crayfish (*O. p. palmeri*), is found from roughly central Arkansas and SE Missouri to W Tennessee, then S through central and W Mississippi into the extreme NW Florida parishes of Louisiana (Walls 2009). The western subspecies, named Western Painted Crayfish (*O. palmeri longimanus*), is found W of the Mississippi River; however, there is a broad area of intergradation (or a cline) with *O. p. palmeri* occurring through much of NE Arkansas. Dr. Raymond W. Bouchard, a crayfish specialist formerly with the Smithsonian Institution, collected the specimens listed below and identified them as clear intergrades between the 2 subspecies, i.e. *Orconectes palmeri* X *longimanus*. Because the taxonomic problem involving intergradation of the 2 subspecies occurs in central Arkansas, the following 7 correctly identified intergrade collections are valuable in resolving the status of the 2 forms, and thus are reported herein.

Collections: *Lawrence Co.*: Village Creek 1.5 mi. (2.4 km) SE of Alicia, AR; 26 July 1976; R. W. Bouchard; (2 female juveniles). Village Creek at Minturn; 26 July 1976; R. W. Bouchard; (3 male juvenile, 3 female juveniles). Village Creek at Minturn; 19 February 1977; R. W. Bouchard; (4 male I, 3 female, 2 female juveniles).

Jackson Co.: Village Creek at AR St. Hwy 14, S of Newport, AR; 27 July 1976; R. W. Bouchard; (2 male juveniles, 2 female juveniles). Village Creek at AR St. Hwy 37, E of Tuckerman, AR; 26 July 1976; R. W. Bouchard; (2 female juveniles). Village Creek at mouth; 27 July 1977; R. W. Bouchard; (1 female juvenile). Village Creek at AR St. Hwy 37; 19 February 1977; R. W. Bouchard; (2 male I).

Procambarus (Ortmannicus) geminus Hobbs 1975 - Twin Crawfish. *Procambarus geminus* was described from specimens collected from near Taylor, Columbia County, AR by Hobbs (1975). Nothing is known about its natural history (Walls 2009). One ovigerous female of *P. geminus* was collected on 26 April 1965.

New locality records for *P. geminus* in southwestern Arkansas are provided here. *Columbia Co.*: Bayou Dorcheat at AR St. Hwy 160, W of Taylor, AR; 20 April 1984; HWR (3 male II, 2 female). Bayou Dorcheat at co. rd. 12, W of Philadelphia, AR; 20 April 1984; HWR (1 male II). Big Creek at AR St. Hwy 371, W of Magnolia, AR; 9 June 1986; HWR (1 male II). Otter Creek at AR St. Hwy 98, W of Emerson, AR; 12 June 1988; HWR (3 male juveniles).

Lafayette Co.: Walker Creek at AR St. Hwy 160, W of Walker Creek, AR; 26 April 1985; HWR; (2 male II, 1 ovigerous female).

CLASS ARACHNIDA

Nephila clavipes (Linnaeus 1767) – the golden orbweaver, golden-silk orbweaver, or banana spider. Being a primarily neotropical genus, *Nephila clavipes* (Figure 1) is the only species that occurs in North America. Historically, it ranged from Central America and through the Gulf Coastal states of the United States, primarily in the warmer portions of the subtropical regions (Comstock 1948, Levi 1980, Evans 2007). More recently, northward expansion of the range away from the coast has been attributed to climate change (Bakkegard and Davenport 2012). Preferred habitat tends to be damp areas with open forest and humidity above 80% (Moore 1977).

Nephila clavipes was first documented in Arkansas in the Ouachita River bottoms, Felsenthal National Wildlife Refuge (FNWR), in Ashley and Union counties of southeastern Arkansas (Tumlison and Robison 2010). They reported 4 individuals at that time. On 5 September 2015, the site was revisited between 1630 – 1830 hrs to determine the status of the population. We searched 3 contiguous areas (GPS 33.156N, 92.112W): a triangular wooded patch, a rectangle into the woods, and a section of forest edge.

Figure 1. An adult female *Nephila clavipes* near the Ouachita River, Union County, AR, September 2015.

The 50 m stretch of forest edge was oriented N-S and was formed by the ecotone of bottomland forest and an open area maintained for boating access to the Ouachita River, with the open edge facing E. The 15 m long base of the triangle was continuous with the line of this edge and consisted of sides of ca. 30 m, generally facing N and S. The rectangle was a relatively open patch of woods with the E border being the forest edge, and extending ca. 45 m into the woods. These 3 areas allowed us to examine whether webs were more common in the woods or edge, and whether they tended to have a particular orientation. Tumlison and Robison (2010) had found all of their spiders on webs facing E-W.

We found 14 *N. clavipes* in the triangle, 8 in the rectangle, and 16 along the edge. Webs were oriented to face openings: N-S in the triangle, E-W in the edge, and variable but generally E-W in the rectangle. Our observations somewhat support the argument of Robinson and Robinson (1974) that compass orientation of webs is determined by position of available web supports, but orientation to an opening that serves as a flight corridor for insect prey seems also to be an important aspect of orientation at our site. In thermally extreme environments, web orientation may be used to reduce absorption of solar heat (Higgins and Ezcurra 1996), but shading at our site likely makes this adaptation unnecessary.

Webs were attached to available anchors, including sticks on the ground, and trees and bushes such as oak, maple, hickory, huckleberry, sweetgum, persimmon, greenbriar, and other vines. Webs also were attached to each other in some cases. Four contiguous webs spanned the E side of the rectangle. Farr (1977) argued that such clumped distribution of webs seems to be influenced by population density of the spiders coupled with limited availability of sites for attachment of webs.

Foods detected in the webs were 5 horseflies (Tabanidae) and 1 praying mantis (Mantidae). Female *N. clavipes* were positioned on the open side of the web, centered about 1.75 m above the substrate (range 0.75 – 3.5 m), and typically hung upside-down in the web.

CLASS INSECTA

Tetraloniella albata (Cresson 1872) – white long-horned bee. This species of small bee is identifiable visually by its white, fuzzy appearance (males have long antennae – Figure 2), and it can be located by audition due to high-pitched sounds of its wing beat (Tumlison and Benjamin 2011). The bee was first documented in Arkansas (MD Warriner *in litt.*) and further studied (Tumlison and Benjamin 2011) at Terre Noire Natural Area (owned by the Arkansas Natural Heritage Commission, ANHC) in Clark County. Conservation of *T. albata*, a species of special concern in Arkansas, requires efforts to maintain or restore prairie clover to suitable sites in blackland prairie environments in southwestern Arkansas (see Foti 1974). In Arkansas, this bee was known previously only from Terre Noire Natural Area in Clark County and Saratoga Natural Area (owned by the ANHC) in Howard County (MD Warriner, *in litt.*).

Tetraloniella albata is oligolectic, meaning it uses only one kind of plant – purple prairie clover (*Dalea purpurea*). This affinity allows researchers to focus survey attempts by first finding the host plant. We visited some remnant blackland prairies where *D. purpurea* is known to occur to search for additional populations of this rare bee.

Columbus Prairie (Sec. 20, T11S, R26W; GPS 33.789N, 93.812W; Hempstead County, owned by The Nature Conservancy) was visited on 6 June 2012 between 1120 – 1300 hrs. Purple prairie clover was present near the entrance to the prairie, and further into the prairie it became quite common and widespread. Flowers on some plants had not begun to bloom, but on average, bloom was about half complete on most prairie clover plants, and *Liatris* was just coming into bloom. We found 29 *Tetraloniella albata* which were most common in areas of very thick growth of *Dalea purpurea* (common enough that 2-3 could be seen simultaneously, which is not common in our experience (Tumlison and Benjamin 2011)).

Figure 2. *Tetraloniella albata* (male) on *Dalea purpurea* at Terre Noire Natural Area, Clark Co., AR, 27 May 2010.

Rick Evans Grandview Prairie (Sec. 16, 17, T11S, R26W; GPS 33.803N, 93.809W; Hempstead County, owned by the Arkansas Game and Fish Commission) was visited on 6 June 2012 between 1330 – 1430 hrs. This locality is across the highway, but otherwise is adjacent to the Columbus Prairie site, but we report results of our search here due to different ownership and land use fragmentation surrounding these habitat islands. Both sites contain populations of purple prairie clover. Although prairie clover was not as dense at Grandview Prairie as it was at Columbus Prairie, and more scattered, we were able to document 6 *T. albata* at 3 sites in Grandview Prairie.

This bee is now documented at 4 sites in 3 counties (Clark, Hempstead, and Howard) in Arkansas, and is expected to occur wherever good historic patches of *Dalea purpurea* remain well established.

Acknowledgments

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Contact Information:
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Russellville, AR 72811
(479)968-0340
mhemmati@atu.edu

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istill@atu.edu

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University of Arkansas at Fayetteville,
AR 72701
cgeren@uark.edu

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Department of Civil Engineering
University of Arkansas at Fayetteville,
AR 72701
rps@uark.edu

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. Our expert reviewers are recruited from within Arkansas, North America, Europe, South America, Australia 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.

Instructions to Authors

A. General requirements

The *JOURNAL OF THE ARKANSAS ACADEMY OF SCIENCE* is published annually. It is the policy of the Arkansas Academy of Science that 1) at least one of the authors of a paper submitted for publication in the *JOURNAL* must be a member of Arkansas Academy of Science, 2) only papers presented at the annual meeting are eligible for publication, and 3) manuscript submission is due at the annual meeting. Manuscripts should be e-mailed to Dr. Ivan Still, the Managing Editor of the Journal (istill@atu.edu), or submitted to the JOURNAL website: http://scholarworks.uark.edu/jaas/, two days before the meeting. The Managing Editor will email an acknowledgement of the receipt of the manuscript before, or the day after the meeting. A hard copy should be handed to the editorial staff at the meeting.

After the meeting all correspondence regarding response to reviews etc. should be directed to the Managing Editor. Publication charges ($50 per page) are payable when the corresponding author returns their response to the reviewers' comments. Publication charges must be sent to the Editor-in-Chief: Dr. Mostafa Hemmati, P.O. Box 1950, Russellville, AR 72811. Please note that the corresponding author will be responsible for the total publication cost of the paper and will submit one check for the entire remittance by the set deadline. If page charges are not received by the deadline, publication of the manuscript will occur in the following year's Journal volume (i.e. two years after the meeting at which the data was presented!) The check **must** contain the manuscript number (assigned prior to return of reviews). All manuscript processing, review and correspondence will be carried out electronically using e-mail. Thus, authors are requested to add the editors' e-mail addresses to their accepted senders' list to ensure that they receive all correspondence.

Original manuscripts should be submitted either as a **feature article** or a shorter **general note**. Original manuscripts should contain results of original research, embody sound principles of scientific investigation, and present data in a concise yet clear manner. Submitted manuscripts should not be previously published and not under consideration for publication elsewhere. The *JOURNAL* is willing to consider **review articles**. These should be authoritative descriptions of any subject within the scope of the Academy. Authors of articles and reviews must refrain from inclusion of previous text and figures from previous reviews or manuscripts that may constitute a breach in copyright of the source journal. Reviews should include enough information from more up-to-date references to show advancement of the subject, relative to previously published reviews. Corresponding authors should identify into which classification their manuscript will fall.

For scientific style and format, the CBE Manual for Authors, Editors, and Publishers Sixth Edition, published by the Style Manual Committee, Council of Biology Editors, is a convenient and widely consulted guide for scientific writers and will be the authority for most style, format, and grammar decisions. Special attention should be given to grammar, consistency in tense, unambiguous reference of pronouns, and logically placed modifiers. To avoid potential rejection during editorial review, all prospective authors are strongly encouraged to submit their manuscripts to other qualified persons for a friendly review of clarity, brevity, grammar, and typographical errors before submitting the manuscript to the *JOURNAL*. Authors should rigorously check their manuscript to avoid accidental plagiarism, and text recycling. Authors should declare any and all relevant conflicts of interest on their manuscripts.

To expedite review, authors should provide the names and current e-mail address of at least three reviewers within their field, with whom they have not had a collaboration in the past 2 years. The authors may wish to provide a list of potential reviewers to be avoided due to conflicts of interest.

Proposed timetable for manuscript processing

Please note: All manuscripts must be properly formatted PRIOR to submission.

In 2017, V. 71 of the *JOURNAL* will begin accepting manuscripts electronically via the *JOURNAL* website: http://scholarworks.uark.edu/jaas/. For all authors submitting via this method, the entire review and publication procedure will be handled via the server.

In this transition year, those authors who would prefer to use the email method, please e-mail your manuscript to the Managing Editor (istill@atu.edu).

For both direct submission and e-mail submissions: Submit your manuscripts a minimum of 2 days prior to the annual meeting.

End of May: Initial editorial review. Manuscripts sent to reviewers.

End of July: All reviews received. Editorial decisions on made on reviewed manuscripts. Manuscripts returned to authors for response to reviewers' critiques. Please email the Managing Editor if you fail to receive your review by the 31st July.

End of August: Authors return revised manuscripts to Managing Editor, or to the *JOURNAL* website, 28 days after editorial decision/reviewers critiques were sent. Corresponding author submits publication charges to the Editor-in-Chief (mhemmati@atu.edu): Mailing address: Mostafa Hemmati, P.O. Box 1950, Russellville, AR 72811. The Managing Editor will send an email reminder approximately 1 week prior to the final due date.

The prompt return of revised manuscripts and payment of publication costs is critical for processing of the *JOURNAL* by the *JOURNAL* staff. If the corresponding author will be unable to attend to the manuscript within the framework of this schedule, then it is the responsibility of the corresponding author to make arrangements with a coauthor to handle the manuscript. NB. The corresponding author will be responsible for submitting the total publication cost of the paper by August 31st. FAILURE TO PAY the publication charges by the deadline will prevent processing of the manuscript, and the manuscript will be added to the manuscripts received from the following year's meeting.

Preparation of the Manuscript

A. General considerations

Format the manuscript as a published paper. If you are unfamiliar with the Journal, please access last year's journal at http://libinfo.uark.edu/aas/ to familiarize yourself with the layout.

1. Use Microsoft Word 2007 or higher for preparation of the document and the file should be saved as a Word Document.

2. The text should be single spaced with Top and Bottom margins set at 0.9″ Left and Right margins, 0.6″. Except for the Title section, the manuscript must be submitted in two column format and the distance between columns should be 0.5″. This can be performed in Word 2007 by clicking on "Page layout" on the Toolbar and then “Columns” from the drop-down menu. Then select "two" (columns).

3. Indent paragraphs and subheadings 0.25″.

4. Use 11 point font in Times New Roman for text. Fonts for the rest of the manuscript must be

- a) Title: 14 point, bold, centered, followed by a single 12 point blank line.
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- d) Corresponding authors email: 10 point, normal, left alignment.
- e) Running title: 10 point, normal, left alignment.
- f) Main text: 11 point, justified left and right.
- g) Figure captions: 9 point, normal.
- h) Table captions: 11 point normal.
- i) Section headings: 11 point, bold, flush left on a separate line, then insert an 11 pt line space. Section headings are not numbered.
- j) Subheadings: 11 point, bold, italic and flush left on a separate line.

6. Set words in italics that are to be printed in italics (e.g., scientific names).

7. In scientific text, **Arabic numerals** should be used in preference to words when the number designates anything that can be counted or measured: 3 hypotheses, 7 samples, 20 milligrams. However, numerals are not used to begin a sentence; spell out the number, reword the sentence, or join it to a previous sentence. Also, 2 numeric expressions should not be placed next to each other in a sentence. The pronoun “one” is always spelled out.

8. A **feature article** is 2 or more pages in length. Most **feature articles** should include the following sections: Abstract, Introduction, Materials and Methods, Results, Discussion, Conclusions, Acknowledgments, and Literature Cited.

9. A **general note** is generally shorter, usually 1 to 2 pages and rarely utilizes subheadings. A note should have the title at the top of the first page with the body of the paper following. Abstracts are not used for general notes.

10. A **review article** should contain a short abstract followed by the body of the paper. The article may be divided into sections if appropriate, and a final summary or concluding paragraph should be included.

Title of a Paper (14 pt, bold, centered)

A.E. Firstauthor[1*], B.F. Second[1], C.G. Third[2], and D.H. Lastauthor[1] (12 point font, normal, centered)

[1]*Department of Biology, Henderson State University, Arkadelphia, AR 71999*
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Running title: (no more than 95 characters and spaces) (10 point, normal, left alignment)

Figure 1. Layout of the title section for a submitted manuscript.

B. Specific considerations

1. Title section

(see Fig. 1 above for layout).

i. It is important that the title be short, but informative. If specialized acronyms or abbreviations are used, the name/term should be first indicated in full followed by the short form/acronym.

ii. Names of all authors and their complete mailing addresses should be added under the Title. Authors names should be in the form "A.M. Scientist", e.g. I.H. Still. Indicate which author is the corresponding author by an asterisk, and then indicate that author's email address on a separate line (see A.4 for format.)

iii. Please include a Short Informative **Running title** (not to exceed 95 characters and spaces) that the Managing editor can insert in the header of each odd numbered page.

iv. Insert a single 10pt blank line after the "Running Title" and add a Continuous section break.

2. Abstract

An abstract summarizing in concrete terms the methods, findings, and implications discussed in the body of the paper must accompany a **feature article** (or **a review article**). That abstract should be completely self-explanatory. A short summary abstract should also be included for any review article. Please review your title and abstract carefully to make sure they convey your essential points succinctly and clearly.

3. Introduction

An appropriate sized introduction should be included that succinctly sets the background and objectives of the research.

4. Materials and Methods

Sufficient details should be included for readers to repeat the experiment. Where possible reference any standard methods, or methods that have been used in previously published papers. Where kits have been used, methods are not required: include the manufacturer's name and location in brackets e.g. "RNA was prepared using the RNeasy Plus Micro Kit (Qiagen, USA)."

4. Tables and figures (line drawings, graphs, or black and white photographs) should not repeat data contained in the text. Tables, figures, graphs, pictures, etc. have to be inserted into the manuscript with "text wrapping" set as "top and bottom" (not "in line with text"). Figures, tables, graphs and pictures can occupy one column (3.4″ wide) or a maximum of two columns wide (7.3″). In the event that a table, a figure, or a photograph requires larger space than a single column, the two column format should be ended and the Table/figure should be placed immediately afterward. The two column format should continue immediately after the Table/figure. To save space, where possible place Tables/Figures at the top or bottom of the column/page.

Tables and figures must be numbered, and should have titles and legends containing sufficient detail to make them easily understood. Allow two 9 pt line spaces above and below figures/tables. Please note that Figure and Table captions should be placed in the body of the manuscript text AND NOT in a text box.

i. Tables: A short caption in 11 point normal should be included. Insert a solid 1.5 pt line below the caption and at the bottom of the table. Within tables place a 0.75pt line under table headings or other divisions. Should the table continue to another page, do not place a line at the bottom of the table. On the next page, place the heading again with a 0.75pt line below, then a 1.5 pt line at the start of the table on the continued page. Tables can be inserted as Tables from Excel, but should not be inserted as pictures from Powerpoint, Photoshop etc., or from a specialized program.

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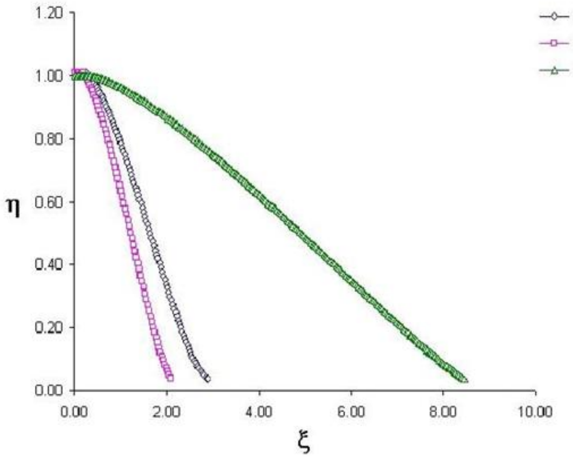

Figure 2. Electric field, η, as a function of position ξ, within the sheath region for three different wave speeds, α.

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Cataloguing and deposition of biological specimens into collections is expected. Publication of manuscripts will be contingent on a declaration that database accession numbers and/or voucher specimens will be made available to interested researchers. Where possible, collector and voucher number for each specimen should be stated in the Results section. The location of the collection should be stated in the Methods section. This will facilitate easy access should another researcher wish to obtain and examine the specimen in question.

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Singleton S and **BC Bennett**. 1997. Handbook of microbiology. 2nd ed. Emmaus (Rodale, PA). Chapter 5, Engineering plasmids; p 285-96.

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Evaluation of a paper submitted to the *JOURNAL* begins with critical reading by the Managing Editor. The manuscript is then submitted to referees for critical review for scientific content, originality and clarity of presentation. To expedite review, authors should provide, in a cover letter, the names and current e-mail address of at least three reviewers within the appropriate field, with whom they have not had a collaboration in the past two years. Potential reviewers that the authors wish to avoid due to other conflicts of interest can also be provided. Attention to the preceding paragraphs will also facilitate the review process. Reviews will be returned to the author together with a judgement regarding the acceptability of the manuscript for publication in the *JOURNAL*.

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GENERAL NOTES

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