

**TRANSACTIONS OF
THE MISSOURI ACADEMY
OF SCIENCE**



VOLUME 36, 2002

About the Academy

Scientists of the State of Missouri organized in 1934 to form the Missouri Academy of Science. By April 6, 1934, a Constitution and By-Laws were prepared and on August 14, 1934, the organization was incorporated.

The purposes of this Academy were presented in the fourth "article of agreement" as follows:

"This corporation is organized, not for profit but for the purposes of promoting the increase and the diffusion of scientific spirit, and of promoting cooperation between the scientific interests of Missouri. It proposes to accomplish these purposes:

- a. By holding meetings for the presentation of scientific papers embodying the results of original research, teaching experience, or other information of scientific interest.
- b. By fostering public interest in scientific matters, through open meetings, press releases and in such other ways as seem feasible.
- c. By encouraging local scientific organizations in every possible way.
- d. By promoting acquaintance in harmonious relationships between scientists in Missouri and among all who are interested in science.
- e. By supplying, so far as finances permit, a medium for the publication of results of original work, particularly those of special interest in this state.
- f. By concerning itself with legislation on scientific matters, and providing opportunity for discussion of such legislation.
- g. By working in any and all other ways which may prove feasible, for the advancement of science in Missouri."

The Academy held its organizational meeting on April 13-14, 1934, with 250 people attending. At the December, 1934,

meeting, more than 400 people registered and by May, 1935, there were approximately 750 members of the Academy. Statewide interest at a high level continued until activities made necessary by World War II caused disruption of Academy affairs except for some activity in the College Section.

Post-war revival of Academy activities started at a meeting on April 20, 1963, at Drury College. From the group of twelve persons who initiated the reactivation of the Academy in 1963, the membership has grown steadily to more than 800. Activities of the Academy have expanded to include the awarding of modest grants for projects proposed by high school and college students, and to sponsor the establishment of a Junior Academy of Science.

Since its reactivation in 1963, the Missouri Academy of Science has regularly held annual meetings at 16 different sites around the state. The refereed publications, the *Transactions of the Missouri Academy of Science*, has been published consistently since 1967. Six Occasional Papers have also been released.

Presently, 36 colleges and universities around the State of Missouri hold an Institutional Membership status. Membership into the Academy is a year-round opportunity for everyone and runs from January 1 to December 31. Benefits include four quarterly *Bulletins*, one annual *Transactions*, and annual meeting lower pre-registration fee.

The Missouri Academy of Science is a non-profit organization and is supported solely by membership dues and donations. That is why we appreciate each new member and the current members who renew so faithfully each year. And it is because of their interest that the Academy continues its success as a fine scientific organization.

**TRANSACTIONS
OF THE
MISSOURI
ACADEMY
OF
SCIENCE**

**Volumes 36
2002**

EDITORS

Anthony R. Lupo
Jay A. Raveill
Cheryl A. Schmidt

COPY EDITOR & DESIGNER

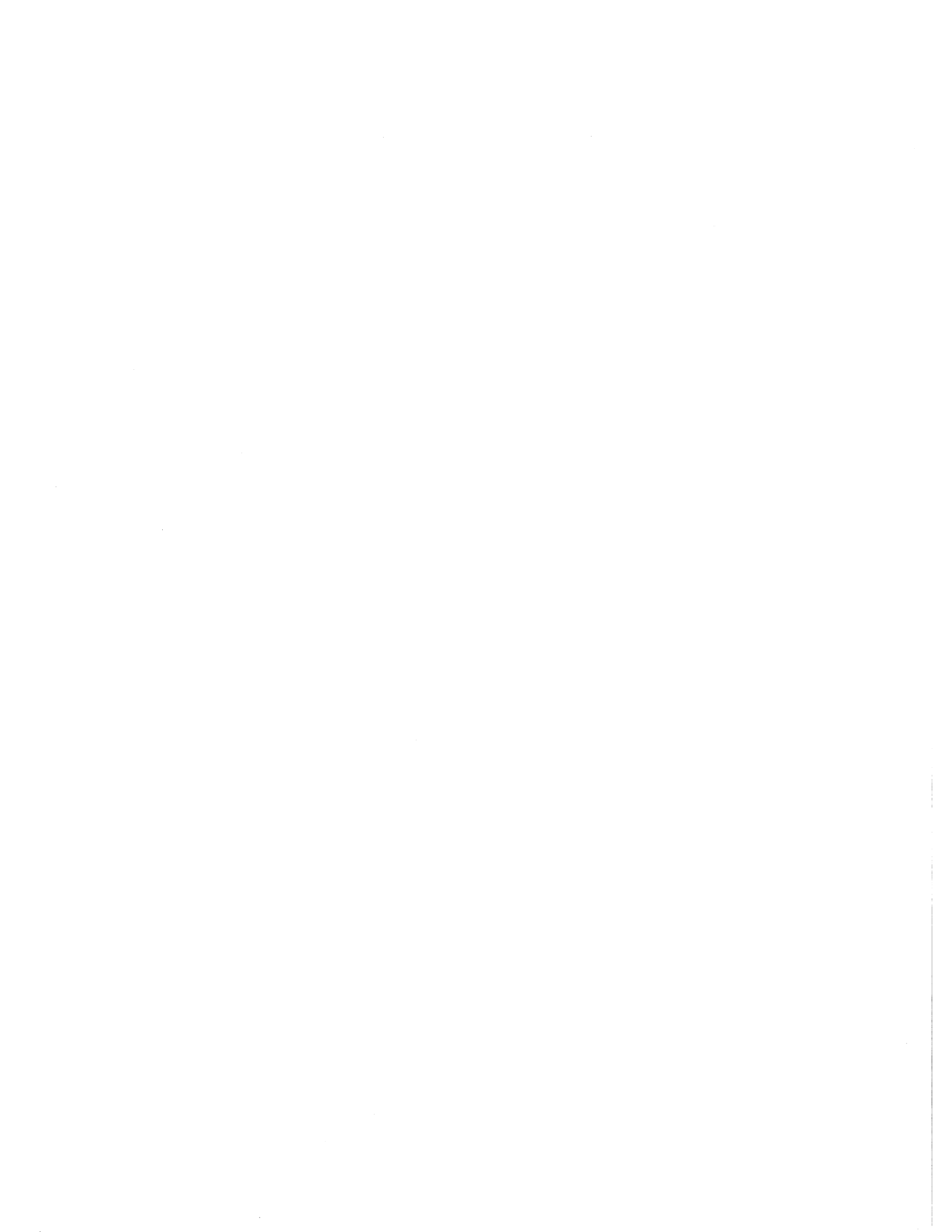
Valerie K. Stalter

EDITORIAL OFFICE

W.C. Morris 306
Central Missouri State University
Warrensburg, MO 64093-5000

BUSINESS OFFICE

Attn: Paula Macy
404 Humphreys Hall
Central Missouri State University
Warrensburg, MO 64093-5053



Missouri Academy of Science

OFFICERS 2001-2002

President	Mary F. Haskins Rockhurst University	President-Elect	Tamera S. Jahnke Southwest Missouri State University
Vice-President	Steven H. Mills Central Missouri State University	Past-President	David R. Naugler Southeast Missouri State University
Secretary	Cheryl A. Schmidt Central Missouri State University	Treasurer	Frederick Worman Central Missouri State University
Historian	Marshall L. Anderson Rockhurst University	Collegiate Division Director	Ted Goudge Northwest Missouri State University
		Junior Division Director	Michelle Norgren Southwest Missouri State University

Publications of the Missouri Academy of Science

The following Volumes of the Transactions of the Missouri Academy of Science are available for purchase.

The charge is \$18.00 per Volume which includes a \$3.00 charge for shipping and handling for domestic postage. Overseas orders should add current postal airmail rate for international mail.

Volumes: 1, 2, 3, 4, 5, 6, 7 & 8 (a double volume), 9, 10 & 11 (a double volume), 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30.

The following Occasional Papers of the Missouri Academy of Science are also available for purchase. The charge is \$8.00 per copy, which includes a \$3.00 charge for shipping and handling

for domestic postage. Overseas orders should add current postal airmail rate for international mail.

1. Symposium on Pests and Pesticides
2. Enzyme Characterization of Brown Recluse Spider Venom
3. Timber-Wildlife Management Symposium
4. Callaway Plant Units I and II, Preconstruction Environmental Monitoring
5. Second Woody Ornamentals Disease Workshop
6. CANCELLED
7. Proceedings of Cedar Glade Symposium - out of print
8. Lyme Disease in the Southcentral United States

Copyright statement: Copyright for each article and abstract in this volume of the Transactions of the Missouri Academy of Science resides with the author(s). Permission to use, copy, or reproduce must be obtained by contacting the respective author(s) of the specific item of interest.

Transactions Of The Missouri Academy of Science

Table of Contents

Volume 36

	Page
Officers of the Academy	ii
Table of Contents	iii
Publications of the Missouri Academy of Science	iv
Contributed Papers	
Energy Conservation Using the Closed Water Loop Heat Pump – <i>Harry J. Sauer, Jr. and Guruprasad Rao</i>	1
A Case Study in Paleocology from the Mississippian of Missouri with a Focus on Chondrichthyan Teeth – <i>Lisa B. Whitenack, Dana R. Elliot, and J.P. Brandenburg</i>	7
Additional Cases of Predation on Horsehair Worms (Phylum Nematomorpha), with a Recent Record for Missouri – <i>Andrew P. Kinziger, Philip A. Cochran, and Joseph A. Cochran</i>	11
Changes in Antler Characteristics from Harvested White-tailed Deer Across 50 Years – <i>Robert E. Kissell, Jr., Christopher G. Wieberg, Lonnie Hansen, and Jeff Beringer</i>	15
Design and Construction of Mourning Dove Research Pens – <i>Tony W. Mong, John H. Schulz, and Joshua J. Millspaugh</i>	21
Effect of Soil pH and Zinc on Rice Cultivars in Missouri – <i>David Dunn, Gene Stevens, Michael Aide, and Justin Horn</i>	25
Hydrolysis of <i>p</i> -Nitrophenyl Acetate: Estimation of Rate Enhancement by Various Catalysts – <i>Debra Nzioka and Allen Scism</i>	29
An Evaluation of an Experimental and a Deepwater Benthic Fish Trap in a Large River System – <i>Jason W. Crites, Valerie A. Barko, and Robert A. Hrabik</i>	33
Harmonic Oscillator Damped by Sliding Friction – <i>Michael Ottinger, Mohammad Samiullah, and Ian Lindevald</i>	39
Construction and Evaluation of a Semi-Portable Radiotelemetry Tower System At Prairie Fork Conservation Area, Missouri – <i>Robert K. Woeck, Joshua J. Millspaugh, and Tony W. Mong</i>	43
Elemental Distributions in Eutric Brunisols from the Northern Glacial Lake Agassiz Region of Manitoba – <i>Michael T. Aide and Gary J. Cwick</i>	49
Determining the Spring to Summer Transition in the Missouri Ozarks Using Synoptic Scale Atmospheric Data – <i>Christopher W. Ratley, Anthony R. Lupo, and Martin A. Baxter</i>	55
Comments on <i>Coenogonium missouriense</i> Davis, a Unique Microlichen from a Cave in Central Missouri – <i>Joseph S. Davis</i>	63
Abstracts	
Papers presented at Annual Meeting, 2002	
Senior Division	66
Collegiate Division	87

Energy Conservation

Using The Closed Water Loop Heat Pump

Harry J. Sauer, Jr. and Guruprasad Rao
University of Missouri-Rolla
Rolla, Missouri 65401

Abstract: The closed water loop heat pump (CWLHP) system has been shown to be an energy conserving building heating and cooling system. Such systems are most applicable where simultaneous heating and cooling needs occur. In these systems, internally generated space heat is used to meet heating needs before external heat is provided from a heating plant. The water loop is the transport system moving heat from where it is not wanted to where it is required. Addition of water storage gives an option to store thermal energy for later use. In the common arrangement for the closed water loop heat pump system, each perimeter zone is served by individual heat pumps while the cores zones are served by a central air handler. This paper reports the results of a study on the effect of component arrangement and system control strategy on the energy saving potential of the water loop heat pump used for heating and cooling of a commercial office building.

Introduction

There has been growing interest in the use and performance of Water Loop Heat Pump (WLHP) systems mainly due to the economic feasibility of the system. Research carried out by Howell (1985) revealed that climates that do not have extreme winters or summers are best suited for WLHP system.

The closed water loop heat pump systems are considered to be energy conserving building heating and air-conditioning systems. They are most applicable where simultaneous heating and cooling needs occur. In these systems internally generated heat is used before adding any external heat. The water loop is the transport system moving heat from where it is not required to where it is required. Addition of water storage gives an option to store energy for later usage. The water loop heat pump system design is similar to a four-pipe fan coil system in some ways. Each perimeter zone is served by individual heat pumps, while the core zones are served by a central air handler. The closed water loop heat pump system is referred to as a semi-central system. The non-central parts of the system are the heat pumps serving each zone separately. The central part is the water loop which carries energy from where it is not required to where it is required. Figure 1 shows a schematic of the Closed Water Loop Heat Pump system.

A typical winter day operation can be explained as follows. Perimeter zones will need heating, while core zones might need cooling because of human occupancy, lighting, equipment etc. Hence water is first passed through the core zones, where the heat pump rejects unwanted space heat from the zone to the water.

The heated water is then passed into the perimeter zone heat pumps, where heat is extracted from the water and rejected into the zone. The closed water loop operation scheme shown in Figure 1 seems to work fine in winter. On performing the simulation, it was observed that the exhaust water temperatures from the core zones reached temperatures as high as 200°F (93°C) on some hot summer days. This hot water would be passed into the perimeter zones which require cooling and therefore the system would be inefficient. From this problem it was realized that water had to be cooled being supplied to the perimeter zones. There were two options to solve the problem.

The first option was inclusion of a cooling tower in the water circuit before allowing water into the perimeter zones, as shown in the Figure 2. The operation in winter will be similar to the old arrangement in that water will not pass through the new cooling tower. However in summer, when the water returning from the core zones is exceeding a preset temperature limit, the cooling tower will be used to cool the water before it is supplied to the perimeter zones. The second option involved allowing water in a parallel circuit to core and perimeter zones. This option is shown in Figure 3. With this option, operating modes for summer and winter are different. In winter, all the water will be passed into the core zones where heat will be picked up, and rejected to the perimeter zones. On a hot summer day, water will be distributed among the core and perimeter zones, thus allowing the perimeter zones to receive the same temperature water as that received by the core zones.

Building HVAC (heating, ventilation and air-conditioning) energy consumption represents a major part in a building's overall energy requirement. This HVAC energy consumption varies significantly with different air handling systems. The HVAC designers require software tools that aid in choosing the ideal system for a given building. The software tools in order to serve the purpose should be able to simulate a variety of HVAC systems, incorporating the state of the art demand and peak load reduction techniques. The simulations are performed every hour for an entire year and the energy meters keep track of the annual energy consumption. Several life cycle costing techniques are incorporated in the program. Based on the output of the simulation program, the designer will be able to select not only the most economical type of HVAC system but also which energy conserving measures will have a reasonable payback.

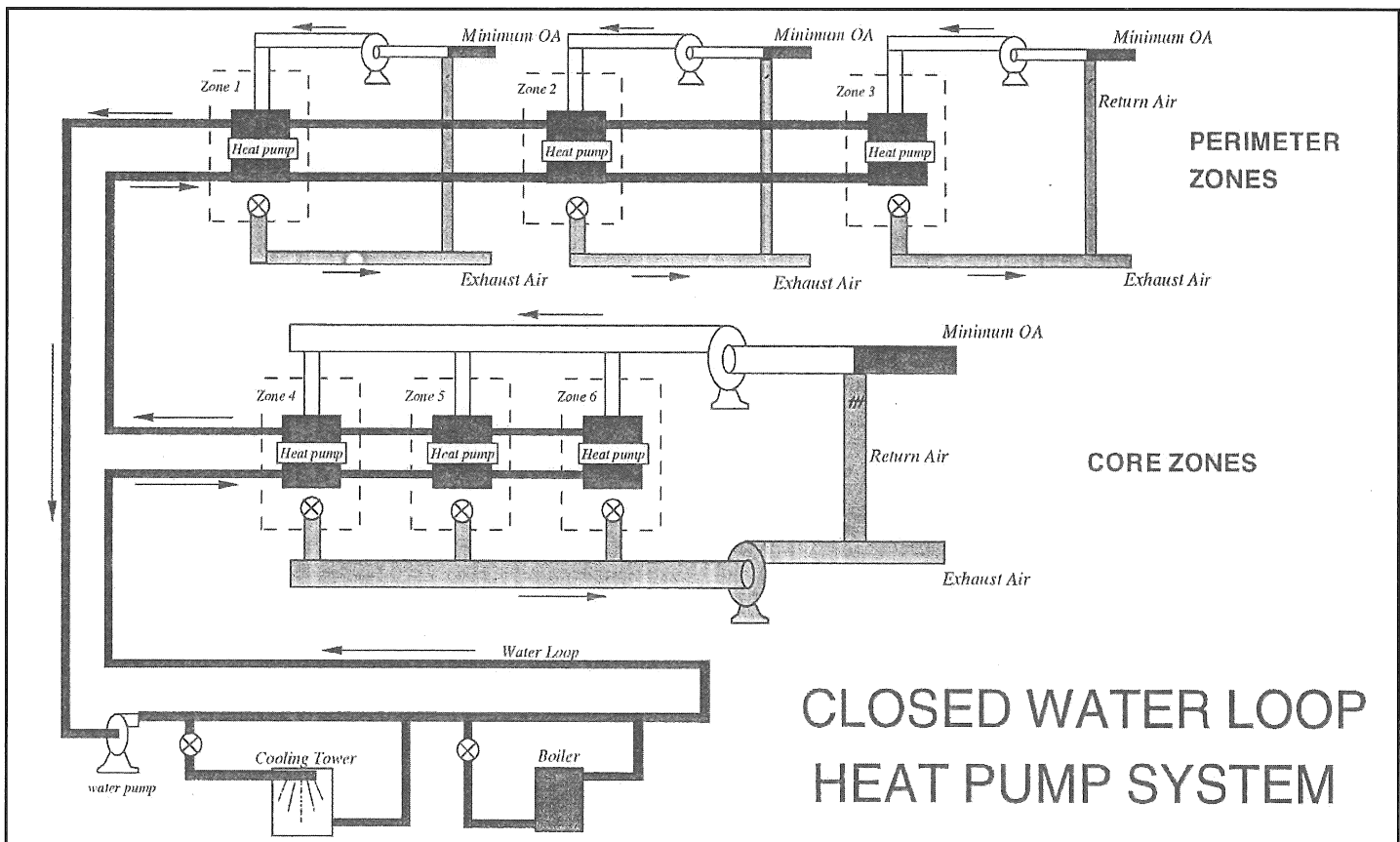


Figure 1. Schematic of Closed Water Loop Heat Pump (CWLHP) System.

Methodology

In the approach selected, the simulation of the building (mainly its physical aspects and internal loads) was separated from the simulation of different types of terminal and primary HVAC systems. The building loads program was made to simulate the building requirements as distinct from any HVAC systems that would provide the heating and cooling. This loads program was then incorporated into the various system programs. The main advantage of this approach was that comparison of different HVAC systems could be performed while being assured of a common basis in terms of building requirements. Only then could effects of the HVAC systems be properly observed. In addition, this approach allowed comparison between heat reclaim and economizer cycle priorities in systems that combined the energy-saving effects of both heat reclaim and economizer cycle operation.

To determine the requirements of the building in terms of sensible cooling, sensible heating, dehumidification and humidification for each hour, an energy balance was performed for each zone of the building on an hourly basis. It must be kept in mind that this analysis was aimed at developing a simplified, reasonably accurate procedure that would provide a common basis upon which different terminal and primary systems could be analyzed and the performance of those systems evaluated with the simultaneous operation of various energy conserving measures. The approach to calculate building cooling loads may be called an "Effective Temperature Difference (ETD)" Method with Time

Averaging (TA). Anantapantula (1993) and Sauer et al (1996) provide details of the method.

Existing HVAC system simulation software from Anantapantula (1993) was expanded for this project by adding a module for the closed water loop heat pump. The program now has the capability for simulating the following secondary HVAC systems: Variable Air Volume, Multizone/Dual Duct, Four Pipe Fan Coil, and Closed Water Loop Heat Pump. The demand and peak load reduction techniques included in all the system simulations are economizers, heat reclaim, and thermal energy storage (TES). The software simulates the HVAC systems with combinations of the energy and/or load reducing techniques, and evaluates the energy consumption for each of the combinations. The software basically consists of four modules. Each module representing a type of HVAC system being simulated. All four modules are statically linked into a single executable. When the software is allowed to continue through the economic analysis, a detailed hour by hour simulation of the HVAC system is performed. Energy meters on the chiller and boiler keep track of the energy consumption. The total annual energy consumption is then the final count on the meters. Based on the detailed output, in terms of dollars and years of payback, the consultant should be able to make the optimal choice.

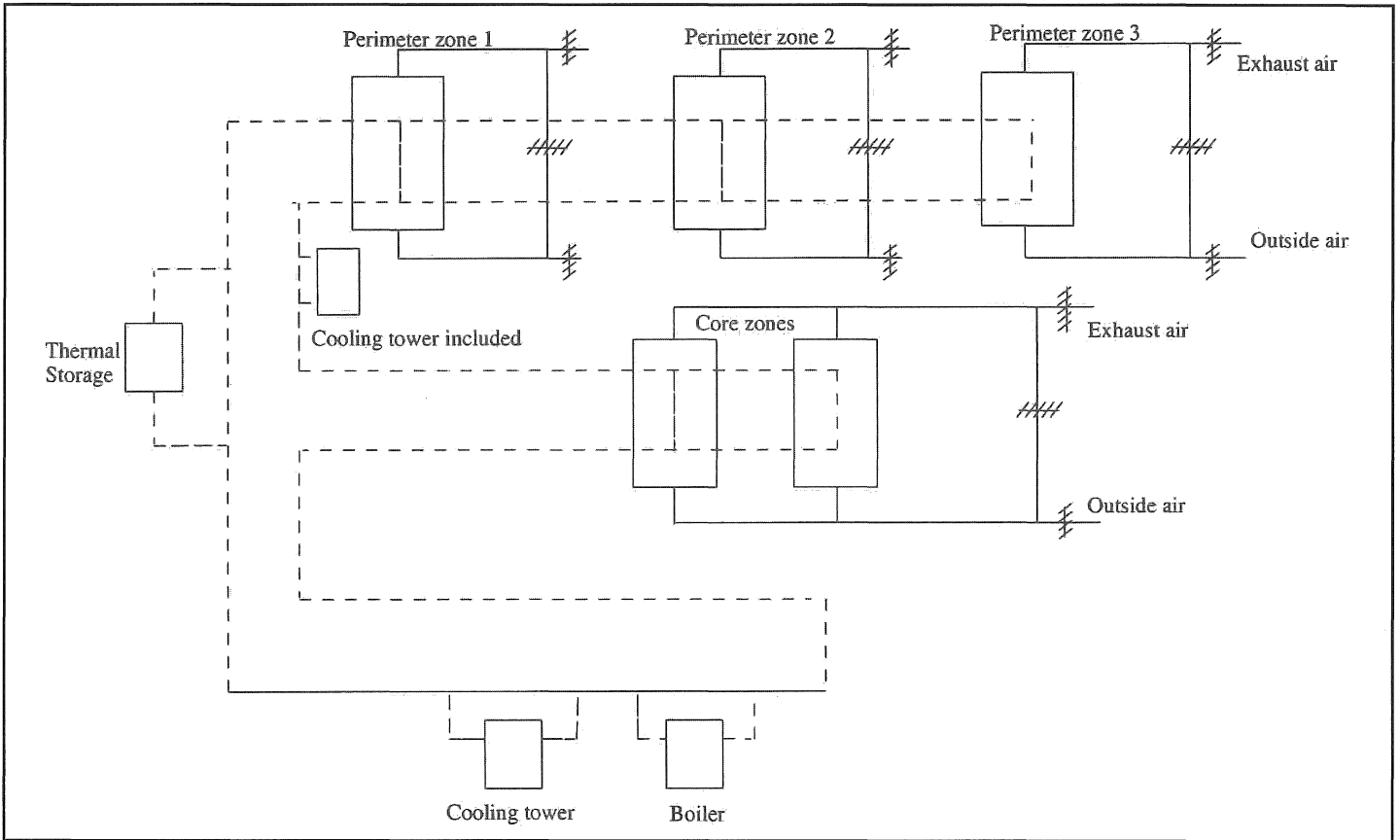


Figure 2. Closed Water Loop Heat Pump System Modification #1.

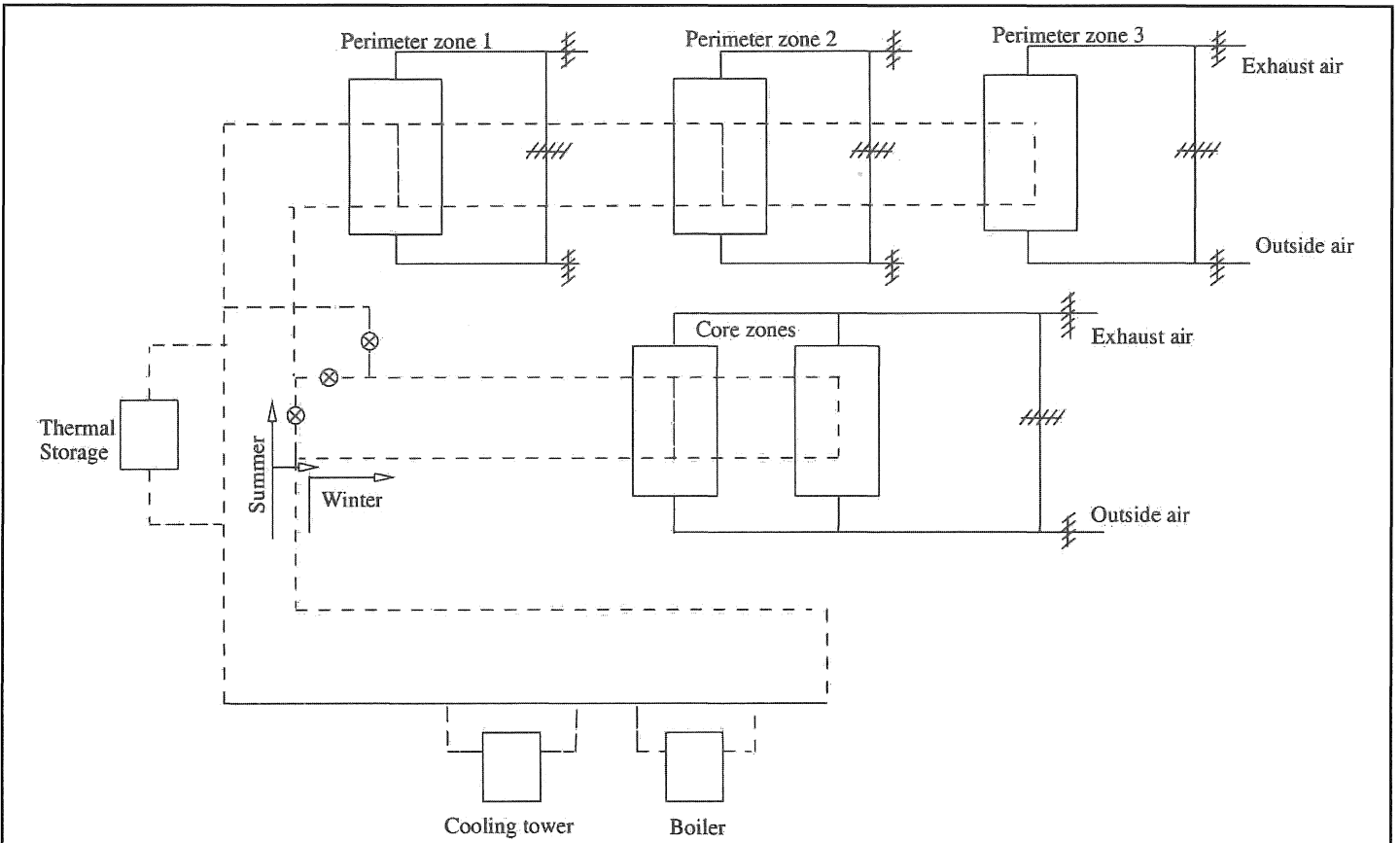


Figure 3. Closed Water Loop Heat Pump System Modification #2.

Input Data

The input data required by the program are mainly in the form of three types of data files, one containing data pertaining to the physical description and load schedule of the building, another providing details of the HVAC system operation, and three containing hourly weather data. To simulate the building in a particular location, the software requires three weather data files: cooling design day weather data, heating design day weather data, and hourly weather data for the entire year.

Building File. The program has the capability to calculate building loads for any number of zones. One line of data is input for each zone. In addition, the program can account for exterior walls facing any two directions and glass areas in each of those walls, in each zone of the building. Input data which must be specified for each zone are: roof, floor, wall, and glass areas and U-factors; ceiling height; building orientation; number of people during occupied period; and internal load level.

Weather Files. The weather data used for the programs came from U.S. Weather Bureau (now the National Weather Service) hourly data, provided on magnetic tape. The original data contained dry bulb temperature, relative humidity and cloud cover for every hour of the year (8760 hours). Subbarao (1990) has covered the calculational logic for determining the total normal intensities and solar heat gain factors for each orientation (North, South, East, West and Horizontal). The weather data available for each hour is comprised of: dry bulb temperature, humidity ratio, total normal intensities on walls facing North, East, South, West and on a horizontal surface, and solar heat gain factors for windows facing North, East, South, West and on a horizontal surface. Weather data files are been prepared for some 60 cities in the U.S. and can simply be copied to the user's hard drive.

HVAC Systems File. The modified HVAC Simulation Software is capable of simulating four types of HVAC systems: Variable Air Volume, Constant Volume Dual Duct, Four Pipe Fan Coil, and Closed Water Loop Heat Pump. For each system evaluated, a data file must be prepared prior to executing the program. The data for the life cycle cost estimation are included in this file. The systems file for the Closed Water Loop Heat Pump must include a rather complete description of the operating conditions and performance data for the CWLHP equipment and system. This file requires the following:

- Minimum OA Required
- Economizer Temperature Setpoint
- Preheat Coil Temperature Setpoint
- Supply Fan Static Pressure and Efficiency
- Cooling Coil Discharge Temperature and Humidity
- Hot Deck Maximum and Minimum Temperatures at corresponding OA Temperatures
- Chiller COP
- Boiler Efficiency
- Maximum storage capacity for heating, hours for reset
- Cost of energy
- Investment cost of installed energy conserving devices
- Years desired for payback
- Discount rate
- Escalation rate
- Expected life of equipment
- Circulating Water Pump Unit Size and Efficiency

- Water Side Pressure Drop
- Minimum and maximum piping loop water temperatures
- Cooling tower "approach"

Sample Results

The building that was simulated in this study was modeled after an existing two story, all electric office building located in St. Louis, Missouri. The building was divided into 16 zones. Physical description and building operation (base case) data were as given below.

Building roof area	: 22,810 ft ² (2119 m ²)
Building floor area	: 45,620 ft ² (4238 m ²)
Building exterior wall area	: 9,460 ft ² (879 m ²)
Building glass area	: 7,536 ft ² (700 m ²)
	(44% of Exterior Wall Area)

Each zone had an internal load density of 2.9 W/ft² (31 W/m²). The building had 408 people for the base case and this number was prorated as per floor area for each zone. The zone ceiling height was 8.5 ft (2.59 m). The U-factors used were 0.25 Btu/hr ft² °F (0.79 W/m² °C) for the roof, 0.2 Btu/hr ft² °F (0.63 W/m² °C) for the exterior walls and 1.0 Btu/hr ft² °F (3.15 W/m² °C) for the glass surfaces. A shading coefficient (SC) of 0.6 was used to account for interior and/or exterior shading). Other base case settings were as follow:

Inside setpoint: Temperature = 75 °F (23.9 °C)

Relative humidity = 50 %

Building thermal mass : M (Medium)

Building operation: 24 hours/day

Prior to conducting a detailed study on any particular HVAC system, such as the closed water loop heat pump, a more general analysis of potential energy conserving measures for the building in various locations was undertaken. The potential savings available with either heat reclaim alone or in conjunction with an economizer indicated that a more detailed study on the use of the closed water loop heat pump would be worthwhile. There is really no limit to the number of parametric or comparative studies than can be conducted. Thus, only a few examples are presented to demonstrate the unit energy requirements of the closed loop heat pump.

Figure 4 is a plot showing the components of the energy consumption at different locations when operated without storage. Heat pump heating energy and auxiliary boiler heating energy are less in Phoenix and Houston. Figure 5 is a similar plot, except that now water storage is included. As can be seen, there is very little effect on the auxiliary cooling energy but the auxiliary water heating energy change is significant. Auxiliary water heating energy dropped to zero in Houston and Phoenix, with a large drop also found for St. Louis and Minneapolis.

The results of this study demonstrate both the utilization of a simplified PC program for HVAC system selection as well as the potential of the closed water loop heat pump system as an energy efficient alternative to more conventional systems. The CWLHP offers considerable design flexibility and an inherent ability to recover heat in many commercial buildings.

If the result of this preliminary system selection indicates the water loop heat pump system, the designer can then find one or more sources of step-by-step technical design data for specific equipment selection, application, and specification, such as from EPRI (1994).

Conclusions

For more accurate energy estimating, there are a number of main frame and several PC hourly programs currently available. However, the manpower level and related costs required for developing and inputting the required data generally discourage the HVAC designer from utilizing such programs, except for major projects, for the initial selection of the "best" system. The methodology and associated PC program described in this paper offer an economical and easy to use tool for the design engineer during the initial selection process...and one that should properly promote the closed water loop heat pump system as one of the most energy efficient HVAC systems for buildings that have high internal loads and simultaneous heating needs. Although input data have been kept to a minimum, the various subroutines with the overall program have been shown to provide relatively accurate prediction of hourly building loads, energy requirements for the HVAC equipment, and life cycle costs which include investment costs, energy and demand costs, maintenance costs, and account for the time value of money.

References

Anantapantula, Surya, 1993, "Air Conditioning System Performance with Heat Reclaim and Economizer Operation", PhD Dissertation, University of Missouri-Rolla, Rolla, MO.

EPRI. 1994. "Water-Loop Heat Pump Systems. Volume 1: Engineering Design Guide (Revision 1)," EPRI TR-101134-V1R1, Electric Power Research Institute, Palo Alto, CA.

Howell, R.H., 1985, "Energy use in closed loop heat pump systems with variable storage, internal building loads for various geographic locations." Proceedings of CLIMA 2000 World Congress on Heating Ventilation and Air-conditioning, Copenhagen, Denmark.

Sauer, Jr., H. J., S. Anantapantula, and R. H. Howell, 1996, "A Building Loads Program for HVAC System Simulation," ASME Paper 96-WA/HT-17, 1996 ASME International Mechanical Engineering Congress and Exposition, Atlanta, GA.

Subbarao, B., 1990, "Analysis of Flow Rates and Building Pressurization in a Variable Air Volume System," M. S. Thesis T6053, University of Missouri-Rolla, Rolla, MO.

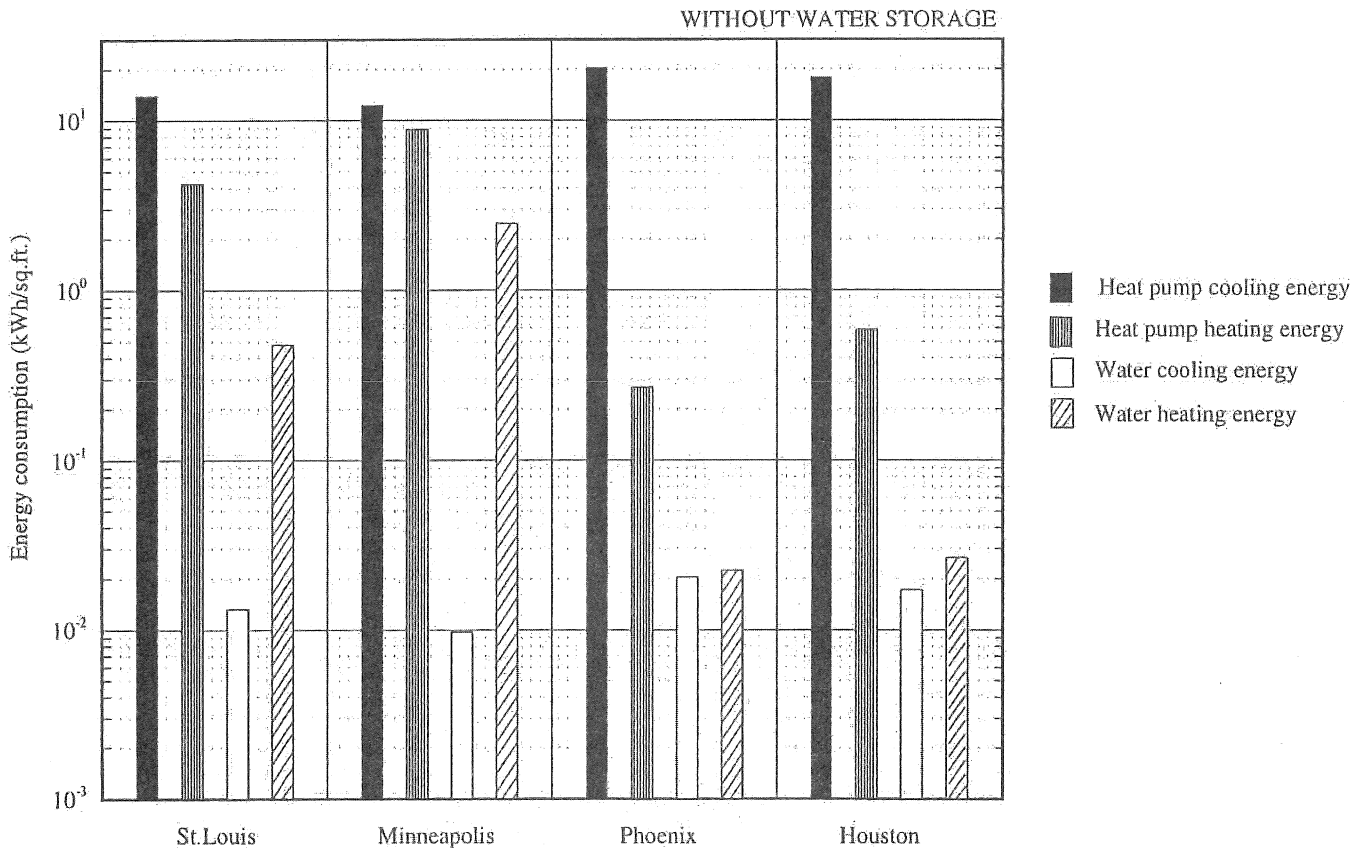


Figure 4. Energy Usage of Closed Water Loop Heat Pump (Without Storage).

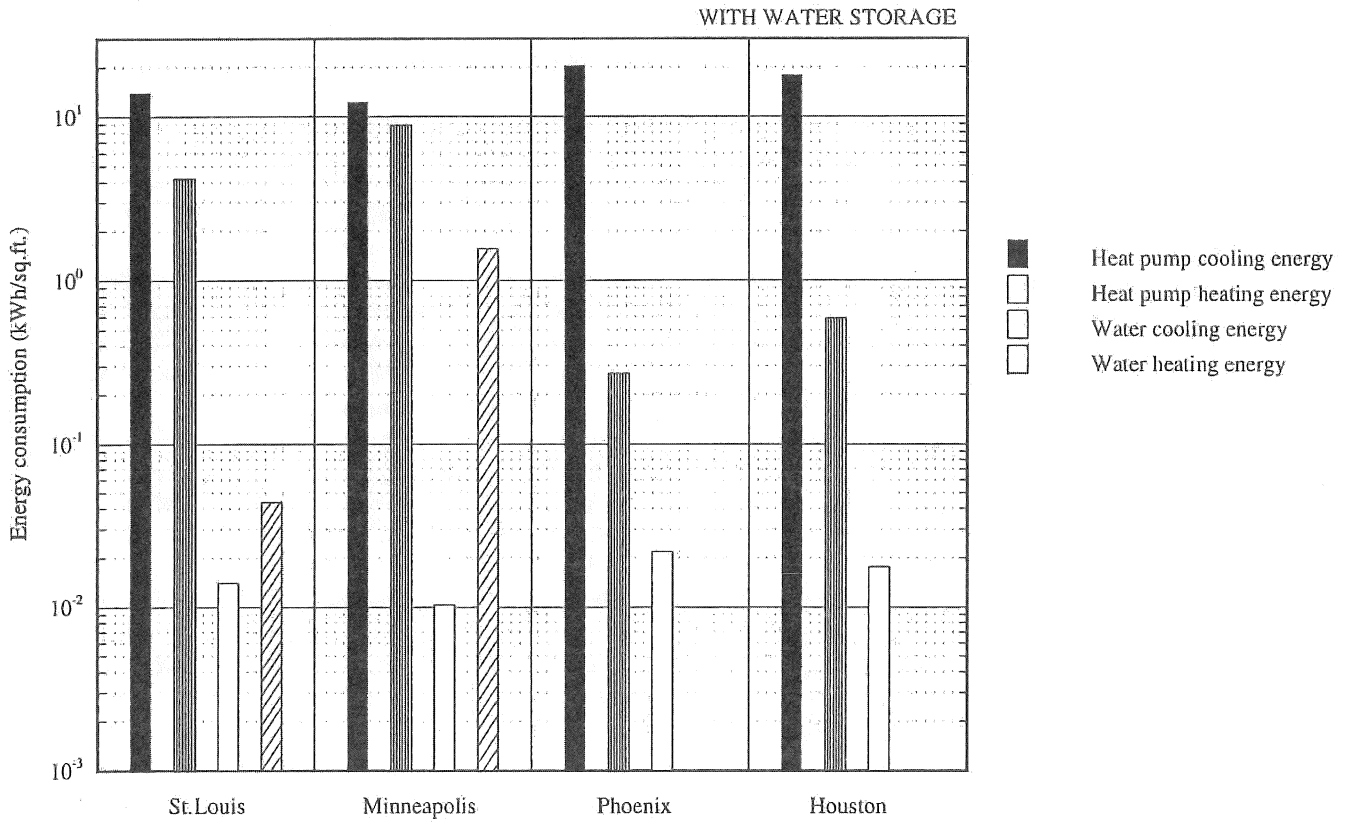


Figure 5. Energy Usage of Closed Water Loop Heat Pump (With Storage).

A Case Study in Paleoecology From the Mississippian of Missouri, With a Focus on Chondrichthyan Teeth

Lisa B. Whitenack

Department of Geology, University of Illinois at Urbana-Champaign, Urbana, IL 61801
(Current address: Department of Biology, University of South Florida, Tampa, FL 33620)

Dana R. Elliot

Department of Biology, Central Methodist College, Fayette, MO 65248

J.P. Brandenburg

Department of Geological Sciences, Michigan State University, East Lansing, MI 48825

Abstract: A suite of fossils collected from the Warsaw Formation (Mississippian) of Missouri includes brachiopods, bryozoans, cnidarians, poriferans, echinoderms, and chondrichthyan teeth. The chondrichthyan fauna includes *Helodus*, *Leiodus*, *Orodus*, *Chomatodus*, *Polyrhizodus*, Xenacanthidae, and Cochlodontidae. Specimens of a questionable nature were also recovered, including several teeth belonging to the form taxon '*Cladodus*' and an unknown tooth. The Warsaw fauna is usually described as a typical Mississippian suspension-feeder benthic community; adding the chondrichthyan fauna provides a more comprehensive picture of the nektonic component of this ecosystem.

Key Words: Chondrichthyes, Warsaw, Mississippian, paleoecology

Introduction

Considerable attention has been paid to the geology and fossil invertebrates of the Mississippian strata of Missouri (e.g. Miller and Collinson, 1951; Spreng and Howe, 1963; Hays, J.B., 1964; Thompson and Fellows, 1969; McKay and Fraunfelder, 1982; Brezinski, D.K., 1986; King, 1986; Thompson, 1986; Carter, 1988; Work et al., 1988; Ausich and Kammer, 1990; Blake and Elliott, in press). However, the vertebrate fauna has been largely ignored. Much of the chondrichthyan material consists of isolated teeth and spines, due to the poor preservation potential of a cartilage. Fragmentary preservation and heterodonty makes identification difficult, but the rich diversity and ecological significance of chondrichthyan fossils makes their study worthy of a greater effort. The present work demonstrates that many of these isolated teeth can be readily identified and included in paleoecological analyses.

Geological Setting

Fossils were collected from surface debris along the Missouri River near Lisbon, Missouri (Howard County, Glasgow, quadrangle, T50N, R18W, Sec. 35). The Mississippian Keokuk and Warsaw Formations are composed mostly of gray fossiliferous limestones interbedded with gray shale and white to gray chert (Thompson, 1986). The boundary between these two sites, both lithographically and biologically, is unclear and has been discussed in a number of papers (Kammer et al., 1989, 1990; Hirt, 1991). Though the locality that the fossils were collected from was previously described as part of the Keokuk Formation (Spreng and Howe, 1963), the presence of *Pentremites conoideus* indicates that this locality is the Warsaw Formation (Waters et al., 1985). Currently, the lithology of the Keokuk and Warsaw Formations is being reexamined (pers. communication, B. Witzke, 1999), and hopefully those studies will yield data that will further support the identification of this locality.

Invertebrate Fauna

The invertebrate fauna is extremely rich and abundant and reflects a typical benthic suspension-feeding community (Table 1). The phylum Porifera is represented solely by disarticulated spicules scattered throughout the rock. Both rugose and tabulate corals (Cnidaria) are present. The Echinodermata are represented by a number of groups: Crinoidea, represented by articulated calyxes and disarticulated columnals and brachials; Blastoidea, represented by columnals and calyxes, especially those of *Pentremites conoideus*; Echinoidea, represented by disarticulated interambulacral plates as well as several largely intact specimens; and Asteroidea, represented by one nearly complete specimen, as well as disarticulated dorsal plates from the same species.

Two identifiable orders of Brachiopoda are present: Spiriferida and Rhynchonellida. From these, two genera from each order could be identified: *Athyris* and *Spirifer*, and *Camartoechia* and *Rynchonella*. The brachiopods showed the most distortion of all

Table 1.

Survey of individuals (N=242)

	Number of Individuals	Percentage of Total Fauna
Brachiopoda	93	38.430
Rugosa	94	38.843
Blastoidea	29	11.983
Crinoidea	25	10.331
Gastropoda	1	0.413

the invertebrate specimens. A number of the *Athyris* specimens were compressed dorso-ventrally, the *Spirifer* specimens were fragmentary, and the rynchonellids were compressed and appeared to be rolled into a ball. For this reason, identification to the species level could not be made.

The most readily identified and most abundant invertebrate fossils are those of the Bryozoa. Bryozoans occurred either as fragmented pieces or as encrusters on other organisms. Three orders were identified: Fenestrata, Cystoporata, and Treptostomata. The fenestrates are the most diverse and abundant, including *Fenestella*, *Ptylopora*, *Hemitrypa*, *Archimedes*, and *Polypora*. The cystoporates include *Actinotrypa*, *Meekopora*, and *Dichotrypa*; the treptostomes are represented by *Leioclima* and *Tabulopora*.

Vertebrate Fauna

The vertebrate fauna, while almost entirely chondrichthyan, is still very diverse. All specimens are single teeth found disassociated from the jaw. The Chondrichthyes are represented by two subclasses: Holocephali and Elasmobranchii. The holocephalans from this suite include *Helodus* (Heliodontidae), *Chitonodus* (Chochliodontidae), and two flat tooth plates that are likely chochliodonts (Figure 1). The elasmobranchs include *Chomatodus* (Petalodontidae), *Polyrhizodus* (Petalodontidae), *Orodus* (Orodontidae), *Leiodus* (Orodontidae), and a xenacanth tooth (Xenacanthidae) (Figure 2).

There are several specimens of questionable nature. One is a single tooth that measures approximately 3.5 mm along the cusp (Figure 3). It is unlikely that it is chondrichthyan, for it appears to be composed of a different material and has a morphology that is not like typical Paleozoic chondrichthyan teeth. The other questionable specimens belong to the form taxon '*Cladodus*' (Figure 4). Teeth assigned to this form taxon generally have one large median cusp and several small accessory cusps on a wide flat base (Zangerl, 1981). Because these teeth were found disassociated from the jaw, a more specific identification cannot be made.

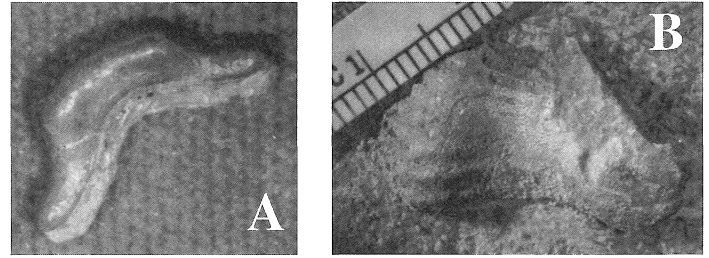
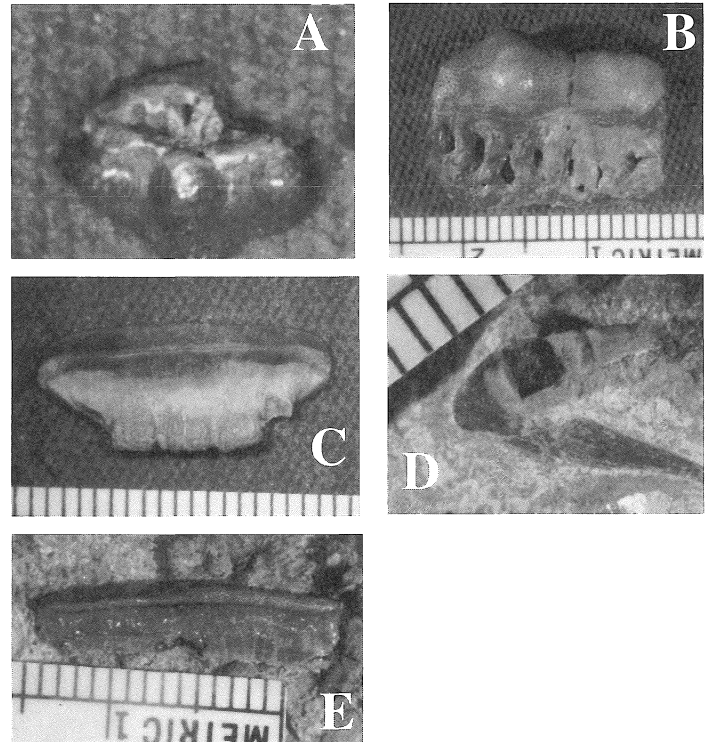
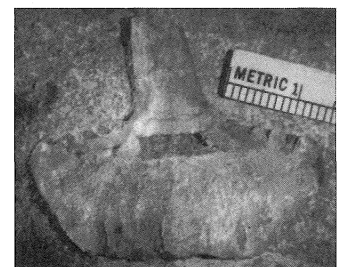
Figure 1. Holocephalii specimens- (A) *Helodus* (B) *Chitonodus*Figure 2. Elasmobranchii specimens- (A) *Leiodus* (B) *Orodus* (C) *Polyrhizodus* (D) Xenicanthidae (E) *Chomatodus*

Figure 3. Unknown tooth

Figure 4. An example of '*Cladodus*'

Paleoecology

The environment these benthic invertebrates lived in was probably one of low energy currents. The fact that fenestrate bryozoans were present, for example, indicates that the energy of the currents must have been somewhat low, for many fenestrates are delicate and would be destroyed in high-energy currents. Many of the blastoid and crinoid stems are extremely thin and may not have been able to withstand high-energy currents. The presence of low energy currents in turn implies that these organisms were most likely well below wave base or in a fairly quiet shallow area. The lack of abrasion of the specimens suggests little reworking.

The flattened and fractured condition of many of the brachiopods seems to contradict this assessment. However, it is possible that the chondrichthyan fauna may be responsible. Some modern chondrichthyans with molariform or pavement-like dentitions, such as horn sharks (Heterodontiformes), bonnethead sharks (*Sphyrna tiburo*), some rays (Myliobatidae), and chimeras (Holocephali), are durophagous (Dean, 1906; Smith, 1942; Cappetta, 1987; Wilga and Motta, 2000). Similar molariform dental morphologies are found in members of the chondrichthyan fauna in this study (*Helodus*, *Chitonodus*, *Leiodus*, *Orodus*, *Polyrhizodus*, *Chomatodus*). There is also fossil evidence for chondrichthyan predation on brachiopods. Brachiopod fragments have been found in preserved stomach contents of *Janassa* (Petalodontidae) and *Fadenia* (Caseodontidae) (Moy-Thomas and Miles, 1971). Other authors have also suggested chondrichthyans as predators on brachiopods (Alexander, 1981; Vermeij, 1983).

Conclusion

The presence of the chondrichthyan ichthyoliths gives a better picture of what the environment of the site was during the Mississippian. When solely looking at the invertebrate fauna, only a picture of the benthic portion of the water column was obtained. By studying the chondrichthyan fauna, the nektonic community can be added to the overall picture. Predation by durophagous chondrichthyans explains the dorsoventral flattening of brachiopod shells in an environment with low energy currents. Difficulty in identifying specimens should not discourage paleoecologists from using these specimens in their analysis.

Acknowledgements

We would like to thank Daniel Blake, Brian Witzke, Robert Anstey, Danita Brandt, and Michael Gottfried for all of their help, support, and encouragement during this project.

References

- Alexander, R.R., 1981. Predation scars preserved in Chesterian brachiopods: probable culprits and evolutionary consequences for the articulate. *Journal of Paleontology*. 55(1): 192-203.
- Ausich, W.I. and Kammer, T.W., 1990. Systematics and phylogeny of the Late Osagean and Meramecian crinoids *Platycrinites* and *Eucladocrinus* from the Mississippian stratotype region. *Journal of Paleontology*. 64(5): 759-778.
- Blake, D.B. and Elliott, D.R. in press, 2003. Ossicular homologies, systematics, and phylogenetic implications of certain North American Carboniferous asteroids (Echinodermata). *Journal of Paleontology*.
- Brezinski, D.K., 1986. Trilobites from the Keokuk Limestone (Mississippian) of Missouri. *Annals of Carnegie Museum*. 55(8): 138-143.
- Cappetta, H., 1987. *Chondrichthyes II. Mesozoic and Cenozoic Elasmobranchii*. New York: Gustav Fischer Verlag. 193 p.
- Carter, J.L., 1988. Early Mississippian brachiopods from the Glen Park Formation of Illinois and Missouri, *Bulletin of Carnegie Museum of Natural History*. 27: 82 p.
- Dean, B., 1906. *Chimaeroid Fishes and Their Development*. Washington: Carnegie Institution.
- Hayes, J.B., 1964. Geodes and concretions from the Mississippian Warsaw Formation, Keokuk region, Iowa, Illinois, Missouri. *Journal of Sedimentary Petrology*. 34(1): 123-133.
- Hirt, D.S., 1991. Mississippian brachiopod biostratigraphy and the Osagean-Meramecian boundary in south-central Indiana. *Journal of Paleontology*. 65(6): 912-916.
- Kammer, T.W.; Ausich, W.I. and Carter, J.L., 1989. Biostratigraphy of the Osagean-Meramecian boundary in the Mississippian stratotype region. *Geological Society of America Abstracts with Programs*. 21(6): 132.
- Kammer, T.W.; Brenckle, P.L.; Carter, J.L.; Ausich, W.I., 1990. Redefinition of the Osagean-Meramecian boundary in the Mississippian stratotype region. *Palaios*. 5(5): 414-431.
- King, D.T., 1986. Waulsortian-type buildups and resedimented (carbonate-turbidite) facies, Early Mississippian Burlington Shelf, central Missouri. *Journal of Sedimentary Petrology*. 56(4): 471-479.
- McKay, R.H. and Fraunfelder, G., 1982. Trace fossils and environments of deposition of the Aux Vases Formation and the Joppa Member of the Ste. Genevieve Formation (Middle Mississippian) in southeastern Missouri and southern Illinois. *Transactions of the Missouri Academy of Science*. 16: 167 p.
- Miller, A.K. and Collinson, C.W., 1951. Lower Mississippian ammonoids of Missouri. *Journal of Paleontology*. 37(4): 454-487.
- Moy-Thomas, J.A. and Miles, R.S., 1971. *Paleozoic Fishes*. Philadelphia: W.B. Saunders Co. 259 p.
- Smith, B.G., 1942. The heterodontid sharks: their natural history and the external development of *Heterodontus japonicus* based on notes and drawings of Bashford Dean. The Bashford Dean Memorial Volume: Archaic Fishes.

- American Museum of Natural History*. 8: 649-770.
- Spreng, A.C.; Howe, W.B., 1963. Echinoid jaws from the Mississippian and Pennsylvanian of Missouri. *Journal of Paleontology*. 37(4): 931-938.
- Thompson, T.L., 1986. Paleozoic Succession in Missouri. Part 4: Mississippian System. *Missouri Geological Survey Report of Investigations*. 70: 189 p.
- Thompson, T.L. and Fellows, L.D., 1969. Stratigraphy and condont biostratigraphy of Kinderhookian and Osagean (lower Mississippian) rocks of southwestern Missouri and adjacent areas. *Missouri Geological Survey Report of Investigations*. 45: 263 p.
- Van Tuyl, F.M., 1922. The Stratigraphy of the Mississippian Formations of Iowa. *Iowa Geological Survey Annual Reports*. 30: 33-349
- Vermeij, G.J., 1983. Shell-breaking predation through time. In: Tevesz, M.J.S. and McCall, P.L. (eds.) *Biotic interactions in recent and fossil benthic communities*. New York: Plenum Press. pp. 649-669.
- Waters, J.A.; Horowitz, A.S. and Marcuda, D.B., 1985. Ontogeny and phylogeny of the Carboniferous blastoid *Pentremites*. *Journal of Paleontology*. 59(3): 701-712.
- Wilga, C.D. and Motta, P.J., 2000. Durophagy in sharks: feeding mechanics of the hammerhead *Sphyrna tiburo*. *Journal of Experimental Biology*. 203: 2781-2796.
- Work, D.M.; Maples, R.H. and Thompson, T.L., 1988. A new prodromitid ammonoid genus from the Hannibal Shale (Lower Mississippian) of Missouri. *Journal of Paleontology*. 62(5): 772-778.
- Zangerl, R., 1981. *Chondrichthyes I. Paleozoic Elasmobranchii*. New York: Gustav Fischer Verlag. 115 p.

Additional Cases of Predation On Horsehair Worms (Phylum Nematomorpha), With a Recent Record for Missouri

Andrew P. Kinziger

Department of Biology, Saint Louis University, St. Louis, MO 63103

Philip A. Cochran

Division of Natural Sciences, Saint Norbert College, DePere, WI 54115

(Current address: Department of Biology, Saint Mary's University, Winona, MN 55987)

Joseph A. Cochran

Department of Biology, Saint Mary's University, Winona, MN 55987

Abstract: We recovered horsehair worms (*Gordius difficilis* and *G. robustus*) from the digestive tracts of two fish species, longear sunfish (*Lepomis megalotis*) and brown trout (*Salmo trutta*), from seven streams in Missouri and Minnesota. Horsehair worms occurred in more than one fish at one site, and in two streams in more than one year. Horsehair worms have not been recently documented from Missouri, and they have not been previously reported from Fillmore County, Minnesota.

Key Words: *Gordius difficilis*, *Gordius robustus*, Phylum Nematomorpha, *Lepomis megalotis*, *Salmo trutta*, Centrarchidae, Salmonidae, Minnesota, Missouri

Introduction

Horsehair worms (Phylum Nematomorpha) are most commonly encountered during their free-living adult phase, when they occur in a variety of freshwater habitats as elongate, slender, slow-moving worms (Poinar 2001, Smith 2001). Sometimes they are found in tangled aggregations of many individuals. Adult horsehair worms do not feed, but immature individuals are internal parasites of terrestrial or aquatic invertebrates, depending on the species.

Horsehair worms as a group are widely distributed but understudied. Many details of the geographic ranges and life histories of individual species remain to be elucidated (Poinar 2001; Smith 2001). Recently, Cochran et al. (1999) and Poinar (2001) reported several cases of predation on adult horsehair worms, and Cochran et al. (1999) summarized previous anecdotal accounts in the literature. In addition, Bolek and Coggins (2002) removed three *Gordius difficilis* from the intestines of two green frogs (*Rana clamitans*), but they did not indicate whether they thought that the worms were preyed upon directly or had been present initially in other invertebrates consumed by the frogs. Most observations of predation on horsehair worms involved their consumption by freshwater fish, but horsehair worms have been

reported in the diets of only a small proportion of fish populations and typically make up at most a trace component of the diet. Moreover, most individual fish offered horsehair worms in laboratory feeding trials ignored or rejected them (Cochran et al. 1999).

The purpose of this note is to report additional cases of predation by fish on horsehair worms. These provide new insight into the potential importance of predation as a source of mortality in this group.

Methods

Evidence for predation on horsehair worms was obtained opportunistically subsequent to fish collections by seining or angling. Horsehair worms encountered as prey were preserved in 70% ethanol and archived in the invertebrate collection at the Milwaukee Public Museum. All fish lengths reported below are total lengths.

Identification of horsehair worms to species can be difficult (Poinar 2001, Smith 2001). Cochran et al. (1999) identified horsehair worms from several sites in Wisconsin and Minnesota as *Gordius robustus*, the only species in the genus previously reported from the Midwest (Chandler 1985, Watermolen and Haen 1994), on the basis of the presence in males of a bilobed posterior and a post-cloacal crescent. Subsequently it was shown that another species of *Gordius* also inhabits the Midwest. *Gordius difficilis* was originally described as *G. aquaticus difficilis* from a single North Carolina male by Montgomery (1898), but he later synonymized the species with *G. robustus* (1907). Smith (1994) used a series of 16 specimens from Massachusetts to resurrect *G. difficilis*. Hanelt and Janovy (2000) and Bolek and Coggins (2002) reported *G. difficilis* from Nebraska and Wisconsin, respectively, and examination of specimens from the sites in Wisconsin and Minnesota where Cochran et al. (1999) reported *G. robustus* has revealed that they were *G. difficilis* (Bolek, personal communication; Cochran, in review). For this

study, *G. difficilis* was distinguished from *G. robustus* by its lack of a dark ring behind the calotte (the anterior tip of the body), its paler white or off-white coloration (*G. robustus* tends to be reddish brown), its more slender body, and, in males, the presence of a parabolic fringe of hairlike processes anterior to the cloaca.

Results

We found horsehair worms in the digestive tracts of two fish species at seven locations in Missouri and Minnesota:

(1) A longear sunfish (*Lepomis megalotis*), 13.2 cm long, was collected on 7 March 2000 by seining in the North Fork White River at Highway 14/181, Douglas County, Missouri. It had approximately 6 cm of a horsehair worm protruding from its anus; a smaller separate segment that included the anterior end of a worm was found in the colon. Unfortunately, the diagnostic posterior end of the worm was unavailable, but the worm was similar in color (reddish brown), relative thickness, and overall appearance to a female horsehair worm with an unlobed posterior discovered entwined with an elongate egg mass on the previous day in the Strawberry River at Highway 289, Izard County, Arkansas. The latter worm is tentatively identified as a *G. robustus*, a species previously known from Arkansas (Chandler 1985).

(2) Horsehair worms were found in three of five brown trout (*Salmo trutta*) collected by angling on 20 June 1999 in Gilmore Creek on the St. Mary's University campus, Winona County, Minnesota. Worms occurred in two of the three smallest trout (20-25 cm long), with three worms in one fish and one in the other. The largest trout (39 cm) contained a single worm in addition to a house mouse (Cochran and Cochran 1999). The only worm saved for preservation was a female *G. difficilis*. A trout containing horsehair worms was collected at this site in 1997 (Cochran et al. 1999).

(3) A female *G. difficilis* was found in one of four brown trout (28-30 cm long) collected by angling on 20 July 2000 in Garvin Brook, Winona County, Minnesota. The fish that contained the worm was 29 cm long. This sample of trout was collected approximately 2 km downstream from a site where a trout that contained horsehair worms was collected in 1995 (Cochran et al. 1999).

(4) A male *G. difficilis* was found in one of two brown trout (26-28 cm long) collected by angling on 18 June 2000 in an unnamed tributary to Diamond Creek, Fillmore County, Minnesota.

(5) Two male *G. difficilis* were found in one of three brown trout (20-35 cm long) collected by angling on 19 June 2000 in Gribben Creek along County Road 23, Fillmore County, Minnesota. The trout that contained the worms was 26 cm long and was one of two fish that contained slugs and insects of terrestrial origin. The latter were apparently washed into the creek by rain within the previous 24 hours.

(6) A male *G. difficilis* was found in one of ten brown trout (23-25 cm long) collected by angling on 24 June 2001 in Beaver Creek (Whitewater River basin), Winona County, Minnesota.

(7) Anglers D. Hoffman and N. Sitzman provided us with a horsehair worm removed from a trout collected on 4 September 2002 in the South Branch Whitewater River, Winona County, Minnesota, along with a living worm found at the same site. The posterior end of the worm from the trout was missing and the intact specimen was a female. However, both specimens displayed traits associated with *G. robustus*: reddish brown color, relatively large diameter, and a dark ring on the calotte.

Discussion

As in the present account, many previously reported cases of predation on horsehair worms involved fishes of the families Centrarchidae and Salmonidae (Cochran et al. 1999). Both sunfishes and trout tend to fall within the size range of predatory fishes that are small enough to retain invertebrates in their diets but large enough to consume horsehair worms. In addition, trout often occur naturally or are stocked into cold spring-fed streams. Recent collections by one of the authors (PAC) suggest that *G. difficilis* occurs frequently in cold spring runs or other spring-fed habitats.

Our results, along with those of McLennan and MacMillan (1984), suggest that predation on horsehair worms may occur in at least some habitats at frequencies greater than what is implied by the primarily anecdotal reports summarized by Cochran et al. (1999). Even though our individual sample sizes are small, all four samples of brown trout from southeastern Minnesota that we examined during the summer of 2000 included at least one fish that contained a horsehair worm. Moreover, we have found horsehair worms in more than one fish at the same locality, in fish from more than one locality in the same drainage collected within a short time, and in fish from the same streams (Gilmore Creek and Garvin Brook) collected in different years (Cochran et al. 1999 and this study). Our data provide additional support for the suggestion that predation by fish is a potentially important source of horsehair worm mortality even though horsehair worms are not known to be an important component of the diet of any fish species (Cochran et al. 1999).

At least some of the horsehair worms we recovered from trout came from fish that were collected shortly after significant rainfall. Increased discharge after rains may carry horsehair worms from springs and spring runs into streams where they are more exposed to trout at a time when the trout are predisposed to feed on relatively unfamiliar or atypical prey (e.g., terrestrial items).

Finally, our observations have provided new information on the geographical distribution of horsehair worms. In his review of horsehair worm distribution in the United States, Chandler (1985) included no records of any species of horsehair worm from Missouri. Riley (1877), however, reported *G. robustus* in locusts collected in Missouri, but he did not provide specific locality data. In Minnesota, no horsehair worms have been formally reported from Fillmore County, although Johnson et al. (1949) mentioned that "occasional hairworms (Gordiaceae)" were collected during their biological survey of the Root River basin, a drainage system that includes Diamond and Gribben creeks.

Literature Cited

- Bolek, M.G., and Coggins, J.R. 2002. Seasonal occurrence, morphology, and observations on the life history of *Gordius difficilis* (Nematomorpha: Gordioidea) from southeastern Wisconsin, United States. *Journal of Parasitology* 88:287-294.
- Chandler, C.M. 1985. Horsehair worms (Nematomorpha, Gordioidea) from Tennessee, with a review of taxonomy and distribution in the United States. *Journal of the Tennessee Academy of Science* 60:59-62.
- Cochran, P.A. In review. Horsehair worms (Phylum Nematomorpha) in Minnesota. *Proceedings of the Minnesota Academy of Science*.
- Cochran, P.A. and J.A. Cochran. 1999. Predation on a meadow jumping mouse, *Zapus hudsonius*, and a house mouse, *Mus musculus*, by brown trout, *Salmo trutta*. *Canadian Field-Naturalist* 113:684-685.
- Cochran, P.A., A.P. Kinziger, and W.J. Poly. 1999. Predation on horsehair worms (Phylum Nematomorpha). *Journal of Freshwater Ecology* 14:211-218.
- Hanelt, B., and Janovy, J., Jr. 2000. New host and distribution record of *Gordius difficilis* (Nematomorpha: Gordioidea) from a vivid metallic ground beetle, *Chlaenius prasinus* (Coleoptera: Carabidae) from western Nebraska, U.S.A. *Comparative Parasitology* 67:107-108.
- Johnson, R.E., J.B. Moyle, and W.A. Kenyon. 1949. A biological survey and fisheries management plan for the streams of the Root River basin. Minnesota Department of Conservation, *Fisheries Research Investigative Report No. 87*.
- McLennan, J.A. and P.W.H. MacMillan. 1984. The food of rainbow and brown trout in the Mohaka and other rivers of Hawke's Bay, New Zealand. *New Zealand Journal of Marine and Freshwater Research* 18:143-158.
- Montgomery, T.H.J. 1898. The Gordiacea of certain American collections, with particular reference to the North American fauna. *Bulletin of the Museum of Comparative Zoology, Harvard* 32:23-59.
- Montgomery, T.H.J. 1907. The distribution of North American Gordiacea, with descriptions of new species. *Proceedings of the Academy of Natural Sciences of Philadelphia* 59:270-272.
- Poinar, G.O. 2001. Nematomorpha. Pages 280-295 in Thorp, J.H., and Covich, A.P. (editors). *Ecology and classification of North American freshwater invertebrates*. 2nd edition. Academic Press, San Diego, California.
- Riley, C.V. 1877. Ninth annual report on the noxious, beneficial and other insects of the State of Missouri. State Board of Agriculture of the State of Missouri, Jefferson City, Missouri. 129 pp.
- Smith, D.G. 1994. A reevaluation of *Gordius aquaticus difficilis* Montgomery, 1898 (Nematomorpha, Gordioidea, Gordiidae). *Proceedings of the Academy of Natural Sciences of Philadelphia* 145:29-34.
- Smith, D.G. 2001. Pennak's fresh-water invertebrates of the United States, Porifera to Crustacea. 4th edition. John Wiley and Sons, Inc., New York.
- Watermolen, D.J., and Haen, G.L. 1994. Horsehair worms (Phylum Nematomorpha) in Wisconsin, with notes on their occurrence in the Great Lakes. *Journal of Freshwater Ecology* 9:7-11.

Changes in Antler Characteristics From Harvested White-tailed Deer Across 50 Years

Robert E. Kissell, Jr.

Division of Agriculture, Natural Sciences and Mathematics, Lincoln University, Jefferson City, MO 65102.
(Current address: School of Forest Resources, University of Arkansas, Monticello, AR 71656)

Christopher G. Wieberg

Division of Agriculture, Natural Sciences and Mathematics, Lincoln University, Jefferson City, MO 65102.

Lonnie Hansen and Jeff Beringer

Fish and Wildlife Research Center, Missouri Department of Conservation, 1110 S. College Ave., Columbia, MO 65201

Abstract: Current and past geographic variation of antler size of white-tailed deer (*Odocoileus virginianus*) across Missouri is unknown. Our objectives were to determine spatio-temporal patterns and changes of antler characteristics in Missouri between the periods 1951–1970 and 1997–2001. For the early and recent time periods mean beam circumference and mean number of points were determined by county for 1.5-year-old deer. Regression of number of points and latitude/longitude indicated latitude was important during the earlier and latter time periods ($r^2 = 0.75$, $p < 0.0001$; $r^2 = 0.52$, $p < 0.0004$, respectively). Beam circumference also was related latitude during both time periods ($r^2 = 0.73$, $p < 0.0001$; $r^2 = 0.44$, $p < 0.0028$, respectively). Geographic distribution of antler characteristics changed over time. Variation of antler size became less over time and shifted from a north-south distribution to a northwest-southeast distribution. Hypothesized factors influencing recent characteristics include density, nutrition associated with land use practices, and genetics as related to selective harvest criteria.

Introduction

Geographic variation of morphological characteristics of mammals is extensive (Wiig and Andersen 1989, Fandos and Reig 1993, Moncrief 1993, Derocher and Stirling 1998, Arita and Figueroa 1999, Wehausen and Ramey 2000). Morphologic studies focus on cranial characteristics most often. Antler size, as a cranial characteristic, is related to body size (Geist 1998). White-tailed deer body size increases with latitude (Baker 1984), and antler size is expected to increase with latitude as well. Geographic variation studies of white-tailed deer antlers, however, are limited (Maffei et al. 1988, Molina and Molinari 1999).

Many factors are related to antler characteristics in white-tailed deer (McEwen et al. 1957, Short et al. 1969, Roseberry and Klimstra 1975, Cowan and Clark 1981, Jacobson 1984, Sauer 1984, Strickland and Demarais 2000). Among the factors, soil types provide the basis for potential habitat quality, and habitat

quality is considered a proximate factor that affects antler development. At the landscape level, soil types vary spatially and are associated with differences among wildlife populations (Albrecht 1944, Denny 1944, Crawford 1950, Williams and Caskey 1965, Hill 1972, Strickland and Demarais 2000).

Basic geographic relationships of antler characteristics have received limited attention (Strickland and Demarais 2000), and have not been examined in the Midwest. More specifically, how deer antler development varies across the state of Missouri is unknown. Geographic Information Systems (GIS) technology has expanded to a great number of ecological and conservation applications (Grinder and Krausman 2001, Strittholt and Dellasala 2001) such that it is well suited to address morphological patterns at the landscape scale. Our study objectives were to: 1) determine geographic patterns of antler characteristics across Missouri; and, 2) determine if antler characteristic patterns have changed in Missouri over time.

Methods

Antler characteristics (circumference (mm) and number of points) and age (Servinghaus 1949) data were collected from harvested deer at established county check-stations by Missouri Department of Conservation (MDC) personnel and volunteers during 2 time periods, 1951–1970 (early) and 1997–2001 (recent); comparable data were not available during 1971–1996. We assumed the county of harvest was the county in which the animal was checked. An unquantifiable amount of bias may have been in the data, as it was very likely not all yearlings harvested were checked. We believe, however, the bias was consistent and sufficient data were collected to explain the variation. Yearlings comprised the majority of harvest and provided the greatest potential for variation. Therefore, only 1.5-year old males were used in analyses. Because management units used by MDC have changed over time, counties were used as experimental units and years as replicates.

Mean circumference and number of points by county were determined for each time period. Geographic relationships across the state were determined by interpolating data using inverse distance weighting. Linear regressions for each time period were performed using antler characteristics as dependent variables and the latitude and longitude of the center of each county as independent variables. Spatially, counties were well represented across the state except for the extreme west-central and southeastern counties. Comparison of slopes using 95% confidence intervals was conducted to determine if changes occurred over time. All statistical analyses were conducted using SAS (SAS Inst., Inc. 2001) and alpha was set at 0.05 unless otherwise noted.

Results

Latitude related significantly ($p < 0.0001$) to the number of points (Points = $-25.747 + 0.758(\text{latitude}) - 0.019(\text{longitude})$, $r^2 = 0.75$, $p < 0.0001$, d.f. = 36) during the early period. During the recent period, latitude related significantly ($p = 0.0012$) to points, but accounted for less variation (Points = $-18.544 + 0.286(\text{latitude}) - 0.133(\text{longitude})$, $r^2 = 0.52$, $p = 0.0004$, d.f. = 23). Longitude, while unimportant during the early time period ($p = 0.8089$), became increasingly important during the recent time period ($p = 0.0667$). Beam circumference also related significantly to latitude ($p < 0.0001$) during the early period (Beam Circumference = $-139.500 + 4.521(\text{latitude}) - 0.320(\text{longitude})$, $r^2 = 0.73$, $p < 0.0001$, d.f. = 37) and the recent period (Beam Circumference = $-77.485 + 2.305(\text{latitude}) - 0.584(\text{longitude})$, $r^2 = 0.44$, $p = 0.0028$, d.f. = 22). The effect latitude had on the number of points became significantly less (95% C.I.: early, $0.586 < b_1 < 0.917$; recent, $0.127 < b_1 < 0.445$) over time, but was not found to differ over time for beam circumference (95% C.I.: early, $3.442 < m_1 < 5.687$; recent, $1.069 < m_1 < 3.602$). Longitude was not found to be related to beam circumference during either time period.

Interpolation of number of points from 1951–1970 showed harvested yearlings north of the Missouri river with 5–7 points and 2–5 points south of the Missouri river. Distribution across the state during the early time period followed a north–south distribution (Figure 1). Interpolation of average number of points from 1997–2001 indicated harvested deer in the northwestern corner of the state with 5–6 points. Yearling bucks with 3–5 points represented the rest of the state. Distribution across the state during the recent time period shifted to northwest–southeast (Figure 1). A difference between interpolations of number of points between the periods indicated a decrease in the north by 1–2 points, and a decrease south of the Missouri River from 0–1 points. However, isolated locations in southern Missouri increased by up to 1 point (Figure 2).

Interpolation of beam circumference for 1951–1970 indicated harvested deer north of the Missouri river had the largest beam circumferences. Distribution of beam circumference across the state also followed a north–south pattern (Figure 3). Interpolation of beam circumference from 1997–2001 showed the largest beam circumferences occurred in the northwest corner of the state. Distribution across the state also was northwest–

southeast (Figure 3). A difference between interpolations of the beam circumference between periods displayed a decrease in the north by up to 9 mm and an increase in the south by up to 6 mm (Figure 4).

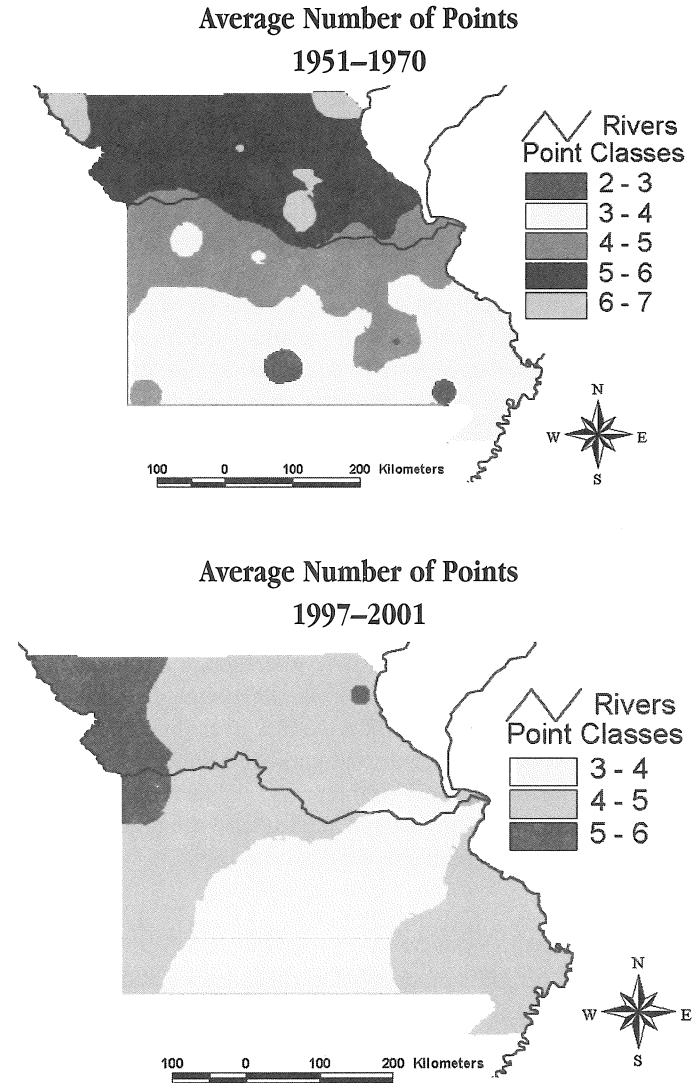


Figure 1. Interpolation of average number of points from harvested white-tailed deer during 1951–1970, and 1997–2001, across Missouri.

**Difference in Average Number of Points
Between 1951–1970 and 1997–2001**

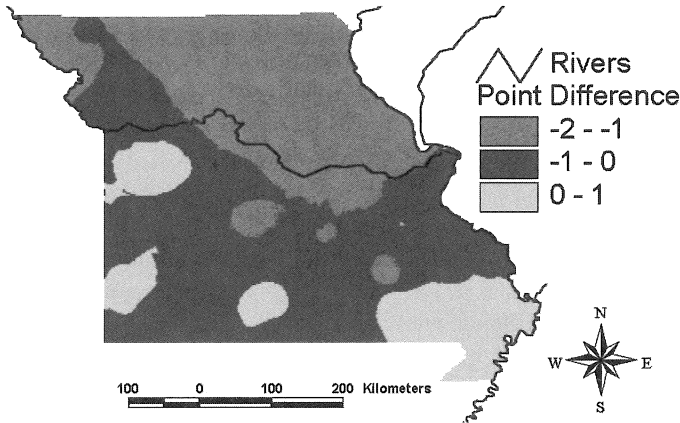


Figure 2. Difference in interpolations between time periods, 1951–1970 and 1997–2001, for number of points from harvested white-tailed deer in Missouri.

**Difference in Beam Circumferences
Between 1950–1970 and 1997–2001**

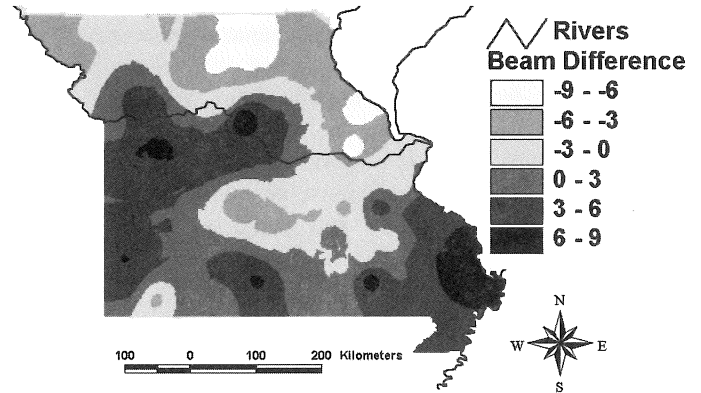
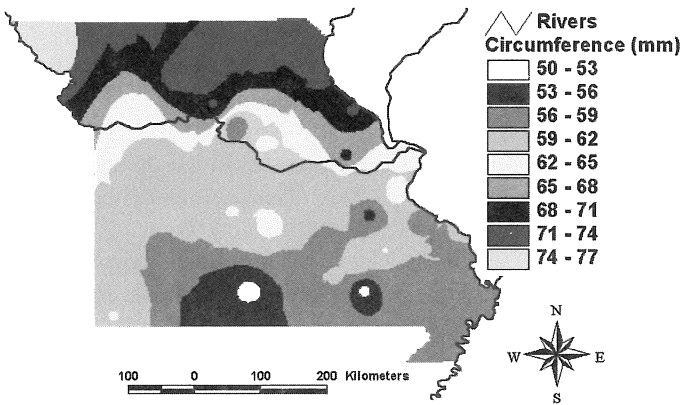


Figure 4. Difference in interpolations between time periods, 1951–1970 and 1997–2001, for beam circumferences from harvested white-tailed deer in Missouri.

**Average Beam Circumference
1951–1970**



**Average Beam Circumference
1997–2001**

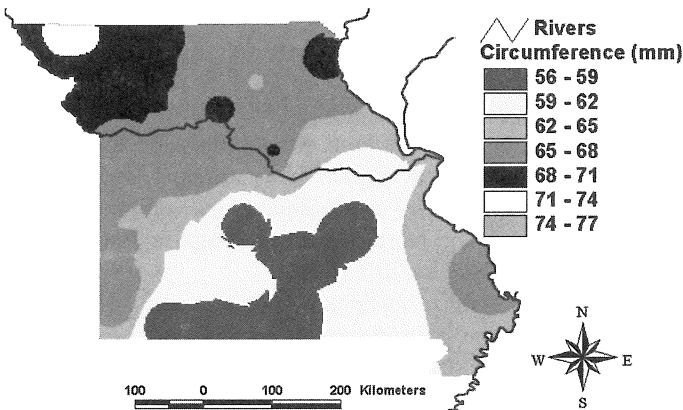


Figure 3. Interpolation of average beam circumference from harvested white-tailed deer during 1951–1970, and 1997–2001, across Missouri.

Discussion

Antler characteristics in Missouri tended to follow a north-south cline during the early time period. Body size is correlated with antler size, and body size increases with increases in latitude (Baker 1984). Superabundant seasonal forage increases with latitude and may have provided for the relationships observed. Environmental differences across the state may have been sufficient to support such a cline during the early time period.

A reduction in the r^2 value in the recent time period regression indicated latitude was not as important during the recent time period. At least three factors may be hypothesized to explain the decline in variation related to latitude. First, density increased through time, and white-tailed deer history in Missouri is typical of many southeastern and mid-western states. Competition with livestock, logging, and market hunting contributed to the decline of deer prior to 1900 (Torgerson and Porath 1984). A deer restoration program began in 1938 and continued through 1957. Approximately 90% of transplanted animals were from Missouri. A harvest season was allowed in 1944 as restoration efforts succeeded. Conservative limits were gradually eased and seasons expanded as the deer population increased. Although deer are difficult to census, population simulations put Missouri's deer herd at over 1,000,000 animals. Improvements in deer mass and antler development are expected after deer herd reduction, though results have been mixed (Roseberry and Klimstra 1975, Shea et al. 1992, Ditchkoff et al. 1997, McCullough 2001). Antler size increased in some portions of southern Missouri despite increasing density, suggesting other factors may be more influential.

Second, nutrition as related to land use may have provided not only the increase in abundance of forage needed for antlerogenesis, but the differences exhibited in a north-south gradient. Oak (*Quercus* spp.) and hickory (*Carya* spp.) forests of the Ozarks are found in the southern third of the state and more agricultural lands are found in the northern third of the state. Transition between the two occurs in the middle of the state. Agricultural crops have been related to increased body size and antler charac-

teristics, and large forested areas have been suggested as sub-optimal habitat for antler growth (Richie 1970).

Genetics as affected through harvest is the third hypothesized factor potentially affecting antler characteristics. Each year Missouri deer hunters collectively spend about 3 million man-days pursuing deer (Hansen, unpubl. data). With such effort, what selective pressure hunting has on antler characteristics over time is unknown. Selective removal has received limited study (Strickland et al. 2001), and most genetic studies are under penned conditions (Lukefahr and Jacobson 1998, Williams et al. 1994).

Further research is needed to determine the relationships among factors influencing antler characteristics at the landscape scale. Hypotheses supporting these relationships include: increased deer densities decrease antler size; land use changes, which affect nutrition, alter antler size; and hunting selects for smaller antler characteristics.

Literature Cited

- Albrecht, W. A. 1944. Soil fertility and wildlife cause and effect. Transactions of the North American Wildlife Conference 9:19-28.
- Arita, H. T., and F. Figueroa. 1999. Geographic patterns of body-mass diversity in Mexican mammals. *Oikos* 85:310-319.
- Baker, R. H. 1984. Origin, classification and distribution. Pages 1-18 in L. K. Halls, editor. White-tailed deer: Ecology and Management. Stackpole Books, Harrisburg, PA.
- Cowan, R. L., and A. C. Clark. 1981. Nutritional requirements. Pages 72-86 in W.R. Davidson F. A. Hayes, V. F. Nettles, and F. E. Kellog, editors. Diseases and parasites of white-tailed deer. Tall Timbers Research Station Miscellaneous Publication 7.
- Crawford, B. T. 1950. Some specific relationships between soils and wildlife. *Journal of Wildlife Management* 14:115-123.
- Denny, A. H. 1944. Wildlife relationships to soils types. Transactions of the North American Wildlife Conference 9:316-323.
- Derocher, A. E., and I. Stirling. 1998. Geographic variation in growth of polar bears. *Journal of Zoology* 245:65-72.
- Ditchkoff, S. S., E. R. Welch, W. R. Starry, W. C. Dinkines, R. E. Masters, and R. L. Lochmiller. 1997. Quality deer management at the McAlester Army Ammunition Plant: A unique approach. Proceedings of the Annual Conference of the Southeastern Fish and Wildlife Agencies 51:389-399.
- Fandos, P., and S. Reig. 1993. Craniometric variability in two populations of roe deer (*Capreolus capreolus*) from Spain. *Journal of Zoology* 231:39-49.
- Geist, V. 1998. Deer of the world: their evolution, behaviour, and ecology. Stackpole Books, Mechanicsburg, PA.
- Grinder, M. I., and P. R. Krausman. 2001. Home range, habitat use, and nocturnal activity of coyotes in an urban environment. *Journal of Wildlife Management* 65:887-898.
- Hill, E. P., III, 1972. Litter size in Alabama cottontails as influenced by soils fertility. *Journal of Wildlife Management* 36:1199-1209.
- Jacobson, H. A. 1984. Relationships between deer and soils nutrients in Mississippi. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 38:1-12.
- Lukefahr, S. D., and H. A. Jacobson. 1998. Variance component analysis and heritability of antler traits in white-tailed deer. *Journal of Wildlife Management* 62:262-268.
- McCullough, D. R. 2001. Male harvest in relation to female removals in a black-tailed deer population. *Journal of Wildlife Management* 65:46-58.
- McEwen, L. C., C. E. French, N.D. Magruder, R. W. Swift, and R. H. Ingram. 1957. Nutrient requirements of the white-tailed deer. Transactions of the North American Wildlife Conference 22:119-132.
- Maffei, M. D., W. D. Klimstra, and T. J. Wilmers. 1988. Cranial and mandibular characteristics of the key deer (*Odocoileus virginianus clavium*). *Journal of Mammalogy* 69:403-407.
- Molina, M., and J. Molinari. 1999. Taxonomy of Venezuelan white-tailed deer (*Odocoileus*, Cervidae, Mammalia), based on cranial and mandibular traits. *Canadian Journal of Zoology* 77:632-645.
- Moncrief, N. D. 1993. Geographic variation in fox squirrels (*Sciurus niger*) and gray squirrels (*S. carolensis*) of the lower Mississippi river valley. *Journal of Mammalogy* 74:547-576.
- Richie, W. F. 1970. Regional differences in weight and antler measurements of Illinois deer. Transactions of the Illinois Academy of Science 63:189-197.
- Roseberry, J. L., and W. D. Klimstra. 1975. Some morphological characteristics of the Crab Orchard deer herd. *Journal of Wildlife Management* 39:48-58.
- SAS Institute, Inc. 2001. The SAS system for windows. Release 8.2. Cary, NC.
- Sauer, P. R. 1984. Physical characteristics. Pages 73-90 in L. K. Halls, editor. White-tailed deer: ecology and management. Stackpole, Harrisburg, PA.
- Servinghaus, C. A. 1949. Tooth development and wear as criteria of age in white-tailed deer. *Journal of Wildlife Management* 13:195-216.
- Shea, S. M., T. A. Breault, and M. L. Richardson. 1992. Herd density and physical condition of white-tailed deer in Florida flatwoods. *Journal of Wildlife Management* 56:262-267.
- Short, H. L., J. D. Newsom, G. L. McCoy, and J. F. Fowler. 1969. Effects of nutrition and climate on southern deer. Transactions of the North American Wildlife And Natural Resources Conference 34:137-145.
- Strickland, B. K., and S. Demarais. 2000. Age and regional differences in antlers and mass of white-tailed deer. *Journal of Wildlife Management*. 64:903-911.
- _____, _____, L. E. Castle, J. W. Lipe, W. H. Lunceford, H. A. Jacobson, D. Frels, and K. V. Miller. 2001. Effects of selective-harvest strategies on white-tailed deer antler size. *Wildlife Society Bulletin* 29:509-520.

- Strittholt, J. R., and D. A. Dellasala. 2001. Importance of roadless areas in biodiversity conservation in forested ecosystems: Case study of the Klamath-Siskiyou ecoregion of the United States. *Conservation Biology* 15:1742-1754.
- Torgerson, O., and W. R. Porath. 1984. Midwest oak/hickory forest. Pages 411-426 in L. K. Halls, editor. *White-tailed deer: Ecology and Management*. Stackpole Books, Harrisburg, PA.
- Wehausen, J. D., and R. R. Ramey II. 2000. Cranial morphometric and evolutionary relationships in the northern range of *Ovis canadensis*. *Journal of Mammalogy* 81:145-161.
- Wiig, O., and T. Andersen. 1989. Lack of geographic variation in the Norwegian lynx (*Lynx lynx*). *Journal of Zoology* 218:326-329.
- Williams, C. E., and A. L. Caskey. 1965. Soil fertility and cottontail fecundity in southeastern Missouri. *American Midland Naturalist* 74:211-224.
- Williams, J. D., W. F. Krueger, and D. H. Harmels. 1994. Heritabilities for antler characteristics and body weight in yearling white-tailed deer. *Heredity* 73:78-83.

Design and Construction Of Mourning Dove Research Pens

Tony W. Mong

Department of Fisheries and Wildlife Sciences

University of Missouri, 302 Anheuser-Busch Natural Resources Building Columbia, MO 65211

John H. Schulz

Missouri Department of Conservation

Conservation Research Center, 1110 South College Avenue, Columbia, Missouri 65201

Joshua J. Millspaugh

Department of Fisheries and Wildlife Sciences

University of Missouri, 302 Anheuser-Busch Natural Resources Building, Columbia, MO 65211

Abstract: To assist with mourning dove (*Zenaida macroura*) research, we designed and built 69 outdoor cages. The cages were flexible in meeting our data collection protocols, and the biological needs of captive wild mourning doves. The basic outside dimensions of the cage were 244 cm high, 183 cm wide, and 183 cm deep with the cage floor 61 cm off the ground, and covered with a corrugated steel roof. The number of different length boards and tools were kept to a minimum to simplify construction. The cages were constructed in 5 weeks with 3 full-time employees (40 hr/week), with incidental assistance from 3 other people. Cost of materials in 2001 for each cage was \leq \$220, including the cost of wood, roofing, wire, and hardware. With minor modifications, the cage design permits research opportunities for a wide range of other avian species to gain knowledge about research techniques and associated ecosystem processes.

Key Words: cage design, Missouri, mourning doves, *Zenaida macroura*

Introduction

Mourning doves (*Zenaida macroura*) are the most studied and heavily hunted migratory upland game bird in North America (Baskett et al. 1993, Mirarchi and Baskett 1994, Tomlinson et al. 1994). Despite extensive and voluminous information, few data exist concerning fundamental management and research questions. For example, why are mourning doves experiencing long-term population trend declines in the Eastern, Central, and Western Management Units as measured by the National Call-Count Survey (Dolton et al. 2001)? Answers to this daunting wildlife management question will involve a series of research projects using a variety of research techniques; e.g., trapping and marking individual birds with leg bands, patagial wing tags, and/or radio transmitters.

Until recently, few biologists have considered the potential negative effects of wildlife research techniques, and the impacts

those effects may have on the resulting data and related management decisions. One of the most problematic issues affecting mourning dove research is determining the effects of attaching and carrying radio transmitters (Schulz and Sheriff 1995). Using relatively small stainless steel cages (24 x 18 x 18 cm) and 200 wild mourning doves kept in captivity, subcutaneously implanted radio transmitters with external antennas were shown to be a preferred attachment alternative to intra-abdominal implants with external antennas (Schulz et al. 1998). Using slightly larger stainless steel cages (24 x 40 x 18 cm) and 195 wild captive mourning doves, subcutaneous radio transmitter implants with external antennas were shown to be a superior to glue attachment based on retention time, and superior to harnesses based on pathological effects (Schulz et al. 2001). Although the size of the cages used in these previous studies were considered within acceptable research guidelines (Mirarchi 1993, Gaunt and Oring 1997), the cages were not large enough to allow the birds to fly; thus, further evaluations must be conducted in larger outdoor pens that simultaneously allow the individual birds to fly while still conducting experiments with relatively large sample sizes of birds. Size, shape, and the number of the outdoor cages are dependent upon the needs of the birds, experimental data collection protocols, cost of materials, and ease of construction. Although several depictions of cages used for mourning dove research have been published (Hanson and Kossack 1963, Mirarchi 1993), they do not provide details on construction or materials. Our objective, therefore, was to design and construct \geq 60 outdoor cages for mourning dove research that would accommodate data collection protocols, would be easily produced, and provide flexibility in meeting the biological needs of captive wild mourning doves. Other avian researchers may find this design useful because it allows flexibility in the type of experiments to be conducted (e.g., studying transmitter effects, understanding patterns in stress hormones, and disease/toxicity testing), and can be used with other avian species with minor modifications.

Cage Design and Construction

To economize labor and simplify construction, we divided the cage construction process into the following steps: cutting lumber, framing cages, cutting wire, attaching wire, attaching roofing, and building/attaching doors. We used pressure-treated chromated copper arsenate (CCA) lumber which resists termites and fungal decay to ensure that the cages would last for several years. When handling the CCA lumber, we followed recommended personal safety guidelines (Material Safety Data Sheet: Product Type, Wolmanized® Treated Wood and Lumber, June 19, 2000; 4 pp). We also kept the number of different length boards to a minimum to reduce the amount of cutting (Table 1). We used 3 x 5 cm welded wire (183 cm wide in 30 m rolls), and 244 x 91 cm galvanized metal roof sheathing. A minimum of hand and power tools were needed to complete pen construction; e.g., wire cutter, electric chop-saw, reciprocating power saw, battery-powered electric drills, and a pneumatic stapler. The basic outside dimensions of the cage were 244 cm high, 183 cm wide, and 183 cm deep with the cage floor 61 cm off the ground, and covered with corrugated steel; the basic size allowed us to use commercially available materials with little waste. Each cage had two doors; one smaller bottom door for daily feeding and watering, and a larger upper door for cage cleaning (Figure 1). Approximately 28 CCA 4 x 9 x 244 cm boards were needed per pen with an estimated 2001 cost of ≤ \$220, including the cost metal roofing and wire; shorter pieces of wood (e.g., corner braces) were made from scrap materials (Table 1).

Table 1. Construction materials and cost of supplies needed to make one mourning dove cage.

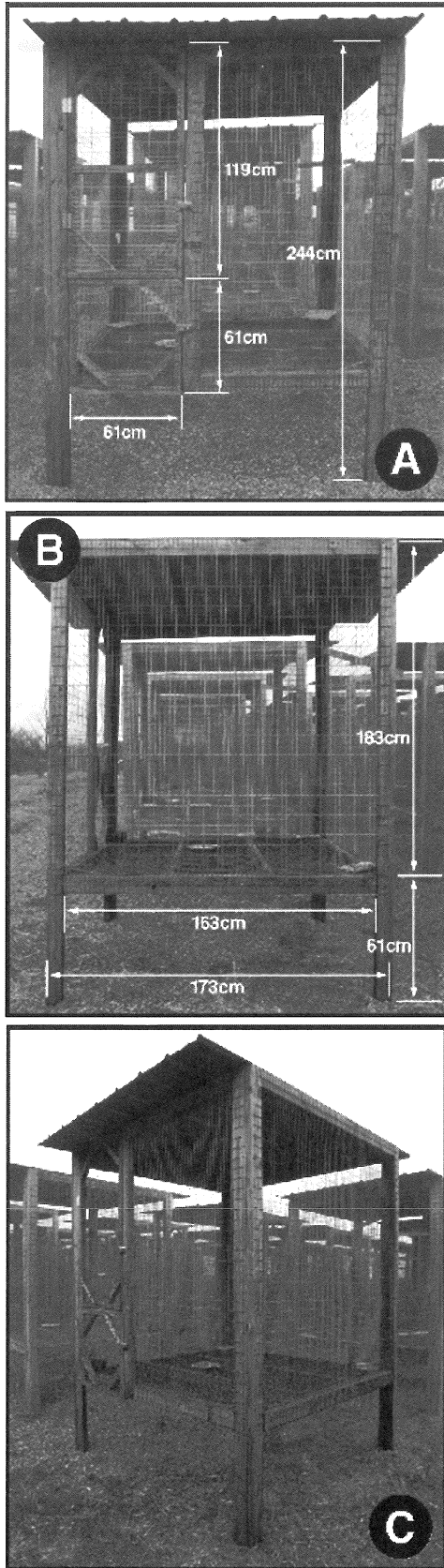
Material	Number of Pieces	Length of Each Peice ¹	Price of All Pieces
CCA Wood (4 x 9 x 244 cm @ \$2.45 apiece)			
	8	244	\$19.60
	12	173	\$29.40
	6	163	\$14.70
	2	81	\$2.45
	1	183	\$2.45
	8	30	(scrap wood)
Wire (3 x 5 cm mesh; 183 x 3048 cm rolls @ \$1.60/30 cm)			
		1006	\$52.80
Metal Roofing (91 x 244 cm @ \$10.00/sheet)			
	2	244	\$20.00
Galvanized screws and staples for pneumatic stapler			\$30.00
Hinges, hasps, and miscellaneous			\$45.00
Total Cost			\$216.40

¹ Lengths measured in cm.

To speed construction, we precut all wood prior to cage assembly (Table 1). Using 6 cm #8 galvanized wood screws, we screwed together two 4 x 9 x 244 cm boards lengthwise to form the cage legs. Next, we framed the basic structure by assembling the two sides of the cage by attaching a 173 cm board across the top of two legs, and another 61 cm from the bottom. We stood the two sides upright, and attached 4 additional 173 cm boards at the top and 61 cm from the bottom to complete the basic square cage frame. To increase the rigidity of the cage, we attached corner braces with 45° cut ends to the inside corners at the top and bottom of the cage. Perpendicular to the cage floor side rails, we attached two 173 cm pieces to provide a stable substrate for the wire cage floor. We attached two additional 173 cm pieces across the top of the cage to provide a surface for roof attachment. Next, we attached 173 cm boards to the outside of the cage frame to provide a flat surface for attaching the welded wire.

The cage floor was built using 2 layers of 3 x 5 cm welded wire separated by the 4 x 9 cm floor braces; the two wire mesh layers reduced the likelihood of predation. First, we tipped the cages over on their sides so we could attach the bottom layer of wire using the pneumatic staple gun. Next, we flipped the cages upright and attached the top layer of wire to the cage floor. After attaching the double cage floor, we attached the pre-cut wire cage to the three sides without doors. We attached the large wire panels by first stapling the center of panel to cage, and then moved towards the edges; this reduced sagging of the wire. We next attached the corrugated metal roofing using galvanized self-tapping roofing screws. The metal roofing was attached to provide approximately 30 cm of overhang on the front and back of the cage, and to fit flush on both sides.

The last step in constructing the cages was to build and attach the doors; much of the material for the doors was obtained from left over scraps. The CCA scrap 4 x 9 cm boards were cut longitudinally (or ripped) on a table saw so that the entire door was made from 4 x 4 cm wood. The smaller bottom door was 61 x 61 cm, and constructed of 2 pieces of wood 61 cm (top and bottom of door) and 2 pieces 53 cm (sides of door; Figure 1). The larger upper door was constructed of 2 pieces of 61 cm (top and bottom of door) and 2 pieces 112 cm (sides of door; Figure 1). After the upper and lower doors were framed, we attached 30 cm corner braces cut with 45° angles on the ends; this provided a stronger door frame and more surface area for attached the wire on the door. Next, we attached pre-cut panels of wire to the doors with the pneumatic stapler. The last step was to attach the doors to the cage with hinges and locking hasps. Once completed, we provided poultry watering jugs and food trays in each cage and used scrap wood placed through the upper cage corners to provide aerial roosting (Figure 1).



Results and Discussion

We built 69 cages in 5 weeks with 3 full-time employees (40 hr/week) and incidental assistance from 3 other people. By creating a simple design that took advantage of commercially available material in standard sizes, we were able to use a minimum of supplies with little waste. Sixty of the cages were placed in 10 rows of 6 cages to provide a facility for experimental research using captive wild mourning doves; 9 other cages were constructed to provide space for stock-piling birds for future research. Our experience indicates the cages provide ample room for individual birds to conduct normal activities (e.g., flying, roosting, feeding), while simultaneously confining the birds in a small enough space to ensure easy capture and collection of necessary data. The cages also provided a setting where newly captured wild mourning doves can be kept with other doves to acclimate to captivity.

Although these cages were designed and used for mourning dove research, the 60 cage facility can provide research opportunities for other species. For example, we used our cages without any modification for pilot experiments dealing with Northern bobwhites (*Colinus virginianus*), Northern cardinals (*Cardinalis cardinalis*), and Eastern cottontail rabbits (*Sylvilagus floridanus*). This adaptability is important because there are numerous future opportunities to conduct experimental research on a whole suite of captive wild birds to gain knowledge about research techniques and their associated ecosystem processes.

Acknowledgments

We thank those individuals who helped with construction of the pens during hot and humid weather; B. Crampton, T. Hinkleman, S. Kistner, C. Rittenhouse, and B. Washburn. Funding for this study was provided by 2001 Webless Migratory Game Bird Research Program (United States Fish and Wildlife Service and the United States Geological Survey–Biological Resources Division), the University of Missouri (Department of Fisheries and Wildlife Sciences), and the Missouri Department of Conservation Research Center (Federal Aid in Wildlife Restoration Project W-13-R).

Figure 1. View of completed mourning dove cages showing measurements of (A) front and (B) side, along with a (C) diagonal view of the colony compound.

Literature Cited

- Baskett, T. S., M. W. Sayre, R. E. Tomlinson, and R. E. Mirarchi, editors. 1993. Ecology and management of the mourning dove. Stackpole Books, Harrisburg Pennsylvania, USA.
- Dolton, D. D., Holmes, R. D., and G. W. Smith. 2001. Mourning dove breeding population status, 2001. U.S. Fish and Wildlife Service, Laurel, Maryland, USA.
- Gaunt, A. S., and L. W. Oring, editors. 1997. Guidelines to the use of wild birds in research. The Ornithological Council Special Publication, Washington D.C., USA.
- Hanson, H. C., and C. W. Kossack. 1963. The mourning dove in Illinois. Illinois Department of Conservation Technical Bulletin 2, Southern Illinois University Press, Carbondale, USA.
- Mirarchi, R. E. 1993. Care and propagation of captive mourning doves. Pages 409-428 in T. S. Baskett, M. W. Sayre, R. E. Tomlinson, and R. E. Mirarchi, editors. Ecology and management of the mourning dove. Wildlife Management Institute, Washington, D.C., USA.
- Mirarchi, R. E., and T. S. Baskett. 1994. Mourning dove (*Zenaida macroura*). The birds of North America, number 117. The American Ornithologists' Union, Washington, D.C., USA, and The Academy of Natural Sciences, Philadelphia, Pennsylvania, USA.
- Schulz, J. H., and S. L. Sheriff. 1995. Evaluation of field techniques for estimating population parameters for mourning doves in central Missouri. Missouri Department of Conservation, Federal Aid in Wildlife Restoration Project W-13-R-49, Final Report.
- Schulz, J. H., A. J. Bermudez, J. L. Tomlinson, J. D. Firman, and Z. He. 1998. Effects of implanted radiotransmitters on captive mourning doves. Journal of Wildlife Management 62:1451-1460.
- Schulz, J. H., A. J. Bermudez, J. L. Tomlinson, J. D. Firman, and Z. He. 2001. Comparison of radiotransmitter attachment techniques with captive mourning doves. Wildlife Society Bulletin 29:771-782.
- Tomlinson, R. E., D. D. Dolton, R. R. George, and R. E. Mirarchi. 1994. Mourning dove. Pages 5-26 in T. C. Tacha and C. E. Braun, editors. Migratory shore and upland game bird management in North America. International Association of Fish and Wildlife Agencies, Washington, D.C., USA.

Effect of Soil pH and Zinc On Rice Cultivars in Missouri

David Dunn and Gene Stevens

University of Missouri-Delta Center, 147 State Highway T, Portageville, Missouri 63873

Michael Aide and Justin Horn

Department of Agriculture, Southeast Missouri State University, Cape Girardeau, Missouri, 63701

Abstract: Approximately 71,000 hectares of rice are planted in Southeast Missouri each year. Many of the irrigation wells used to flood rice fields contain water with high concentrations of calcium carbonate. Soil pH before flooding is often above 6.5 in these fields. Zinc is an important rice nutrient, which becomes less available to plants as soil pH increases. A two year investigation was begun in 1998 on a Crowley silt loam soil (fine, montmorillonitic, thermic Typic Albaqualf) at Qulin, Missouri. The study had the following objectives: (i) determine if elevated soil pH from carbonates inhibits rice Zn uptake, and (ii) determine the efficacy of zinc fertilization on different rice cultivars. A split plot design was used with three replications. Main plots contained different rice cultivars. Cypress, Kaybonnet, and Drew cultivars were drill seeded in main plots. Subplots had annual applications of lime and zinc treatments. Lime treatment levels were no lime (check) and lime. Zinc treatments were untreated, soil applied Zn as $ZnSO_4$, and foliar applied Zn as Zn-EDTA (ethylenediaminetetraacetic acid) chelate. After two years, lime applications increased soil pH from 6.1 to 7.2. Soil pH had a significant effect on the extractable soil Zn following two years of applying $ZnSO_4$ fertilizer. In plots receiving $ZnSO_4$, soil tests from plots without lime averaged $8.9 \text{ mg Zn kg}^{-1}$ compared to soil tests from plots with lime that tested $3.3 \text{ mg Zn kg}^{-1}$. Plant tissue tests showed that soil pH did not significantly effect plant Zn concentrations. In 1999, tissue analysis revealed differences in Zn plant uptake between Zn fertilizer treatments in Kaybonnet and Drew cultivars. Soil applied Zn fertilizer increased Zn concentrations in plant tissue more than foliar Zn. This trend was not observed in Cypress rice. All rice plants contained Zn concentrations greater than 35 mg Zn kg^{-1} . Lime and zinc applications did not significantly effect rice growth or yield in any of the three cultivars.

Introduction

Rice zinc deficiency occurs in Southeast Missouri. When present, the deficiency is usually observed shortly after the permanent flood is established at the first tiller growth stage. Low levels of zinc in rice plants can cause loss of turgidity of the leaves, basal chlorosis of the leaves, delay of plant development, "bronzing" of leaves, and in some cases death of the rice seedlings (Wells et al., 1993). Zinc tissue concentrations generally range from 25 to 150

mg Zn kg^{-1} , with deficiency symptoms appearing whenever the tissue concentrations are less than 20 mg kg^{-1} (Tisdale et al., 1985).

The availability of zinc in rice soils decreases as soil pH increases (Ntamatungiro et al., 1999; Barbosa et al., 1992). Because well water used to irrigate rice in Southeast Missouri is usually high in calcium carbonate, flooding rice fields often has a liming effect, which increases soil pH. Tracy and Hefner (1991) found that the average concentration of Ca in irrigation wells in Butler County, Missouri was 249 part per million. They calculated that applying $1,234 \text{ m}^3$ (1 acre foot) of irrigation water was equivalent to applying 1.9 tonnes of calcium carbonate equivalents per hectare.

Soluble soil Zn concentrations vary greatly in the aqueous phase (2 to $75 \mu\text{g L}^{-1}$), with the specific concentration dependent upon the native amount of soil Zn, the pH, the quantity and type of organic materials, and the character of the adsorbing oxide and clay surfaces (Mills and Jones, 1996). Approximately 65% of the total Zn in the aqueous phase is organically complexed. Sajwan and Lindsay (1986) demonstrated that Zn applications to flood irrigated rice increased the DTPA (diethylenetriaminepentaacetic acid) extractable levels of Zn and decreased the levels of DTPA extractable Mn and Fe. The DTPA concentrations for Zn, Mn, and Fe were proportional to the corresponding metal uptake by rice. Sajwan and Lindsay suggested the elevated levels of Mn might effectively reduce the plant uptake of Zn.

In Arkansas, Slaton et al. (1999) reported that recent field studies suggest that rice yield response to Zn fertilization occur less frequently today than 25 years ago. This may be due to improvements in rice cultivars. On one site, Slaton et al. (1999) found a significant effect on grain yield from the type of Zn fertilizer applied.

The purpose of this investigation was to determine whether elevated soil pH is antagonistic towards Zn uptake in Missouri rice. The secondary objective was to determine the efficacy of zinc fertilization with soil and foliar Zn applications on rice cultivars.

Materials and Methods

A rice study was conducted on a field at the Missouri Rice Research Farm (36°N, 90°W) in Dunklin County, Missouri in 1998 and 1999. Rice was planted on a Crowley series (fine, montmorillonitic, thermic Typic Albaqualf). The soil has a silt loam eluvial horizon which overlies a thick silty clay loam argillic horizon. This is a typical soil for producing drill seeded rice in Southeast Missouri (Garrett et al. 1978). The soil pH_{water} of the surface horizon was 6.2. There was no record of zinc fertilizer ever being applied on the site. The field was conventionally tilled.

The experimental design was a split plot design with three replications. Rice was planted with a grain drill in late May in 1998 and 1999. Main plot treatments were three high yielding, medium season rice cultivars available to Missouri rice producers in 1997 (Minor and Stafford, 1998). The cultivars were Cypress, Kaybonnet, and Drew. Each subplot was 3.1 m wide and 6.2 m long. Subplot treatments were six combinations of lime and Zn fertilization levels. Lime and soil Zn (ZnSO₄) treatments were broadcast by hand on subplots two weeks before planting. The two lime treatment levels were 0 (control) and 4.48 tonnes CaCO₃ ha⁻¹. In 1998, pelletized lime was applied. The value of this lime was 544 effective neutralizing material (ENM) per tonnes. In 1999, calcite agricultural lime (431 ENM per tonne) was applied. Values for lime quality were determined at the University of Missouri Experiment Station Chemical Laboratory. The three zinc treatment levels were 0, 22.4 kg ZnSO₄ ha⁻¹, and 5.6 kg ZnEDTA ha⁻¹. The ZnSO₄ was dissolved in water for each subplot and evenly applied with a watering can. The ZnEDTA was foliar applied in 187 L ha⁻¹ water with a CO₂ backpack sprayer before rice was flooded at first tiller growth stage.

Soil samples of the study area were collected from the 0 to 15 cm depth before planting in 1998 and one month after harvest each year. Soil analysis consisted of pH (water), neutralizable acidity, exchangeable cations (Ca, Mg, K, Na), loss on ignition (LOI), Bray 1 extractable phosphorus, and DTPA extraction and atomic absorption determination of Zn, Fe, Mn, and Cu.

Nitrogen fertilizer was applied at first tiller growth stage immediately prior to flood at the rates of 101 kg N ha⁻¹ as urea on Cypress rice and 84 kg N ha⁻¹ on Drew and Kaybonnet. All plots received 34 kg N ha⁻¹ urea applications at 1.3 cm internode elongation and a second application one week later. Proponil (3,4-dichloropropionanilide) was broadcast at a rate of 4 kg a.i. ha⁻¹ for grass control before the flood was established.

Twenty five new growth rice leaves were collected from each subplot at mid tillering and 1.3 cm internode elongation growth stages in 1998 and 1999. The elemental concentrations of Ca, S, Mg, Al, P, K, Zn, B, Fe, Mn, Cu, Na in the leaves were determined by inductively coupled plasma emission spectroscopy after acid digestion of dried and ground plant tissues. Field measurements involved tiller counts, the number of panicles per row, the number of spikelets per panicle, seed weight, dry matter accumulation, moisture content and yield. The rice was harvested with a plot combine. Grain was collected from 1.5 m wide by 5.2 m long areas from each subplot. Yields were adjusted to 13% seed moisture content. Statistical analyses of the data were pre-

formed with SAS (1990) using General Linear Modeling procedures. Fisher's Protected Least Significant Difference (LSD) was calculated at the 0.05 probability level for making treatment mean comparisons.

Results and Discussion

Soil Characterization

Soil pH was increased in subplots by lime treatments. In 1999 the untreated check was pH 6.1 as compared to 7.3 for lime treatments (Table 1). This was due to two years of lime application on the same subplots. Soil pH had a significant effect on the extractable soil Zn following two years of applying ZnSO₄ (Table 1). Extractable soil Zn in plots that received ZnSO₄ fertilizer and no lime was 63% greater than Zn levels in plots with ZnSO₄ and lime. However, the DTPA extractable Zn was greater than 0.4 mg Zn kg⁻¹ in all plots, suggesting that Zn levels were sufficient for rice production. The extractable Mn values generally reflect the changes in pH associated with the lime treatments. Manganese levels decreased as pH increased. Iron values were not effected. There were no evidence for a Zn x Mn or Zn x Fe interactions, as suggested by Sajwan and Lindsay (1986).

Table 1. Mean effect of lime and zinc applications on soil pH, Fe, Mn and Zn concentrations in 1999.

Applications		pH	Fe	Mn	Zn
		Units	mg kg ⁻¹		
No Lime	No zinc	6.1	108	42.0	1.21
	Soil zinc	6.0	104	35.7	8.91
	Foliar zinc	6.1	107	37.3	3.01
Lime	No zinc	7.2	102	30.3	1.35
	Soil zinc	7.1	97	30.3	3.25
	Foliar zinc	7.2	102	30.3	2.05
LSD _{.05}		0.3	3	5.9	1.85
C.V.%		8	5	30.5	19.8

Tissue Concentrations

The elemental concentrations of S, P, K, Mg, Ca, Na, B, Cu, and Al were typical for normally developing rice (Mills and Jones, 1996). No significant differences in these elements were evident within or among cultivars. In 1998, the concentration of Zn was not effected by cultivars (Table 2). In 1999, a significant interaction between cultivars and zinc fertilizer sources for plant Zn concentration was found. Tissue Zn concentrations associated with soil Zn applications for Drew and Kaybonnet cultivars were significantly greater than for plants in foliar Zn and untreated check plots. There were no differences found in plant Zn uptake in Cypress plots. All Zn concentrations were above the deficiency threshold of 20 mg Zn kg⁻¹, especially for the 1999 trial.

Table 2. Mean effect of lime and zinc applications on rice plant nutrient concentrations at internode elongation growth stage and yield in 1998.

Cultivar	Zinc Application	Fe	Mn	Zn	Rice Yield
		mg kg ⁻¹	mg kg ⁻¹	mg kg ⁻¹	kg ha ⁻¹
Cypress					
No Lime	No zinc	150	1266	44	5242
	Soil zinc	138	1240	34	5393
	Foliar zinc	180	1341	24	5292
Lime	No zinc	159	1247	21	5645
	Soil zinc	147	1105	36	6098
	Foliar zinc	184	1289	27	5544
Kaybonnet					
No Lime	No zinc	232	1772	36	7560
	Soil zinc	183	1698	28	6754
	Foliar zinc	140	1629	30	7510
Lime	No zinc	165	1827	31	6754
	Soil zinc	183	1569	36	6905
	Foliar zinc	119	1178	32	6552
Drew					
No Lime	No zinc	132	1392	37	6804
	Soil zinc	176	1758	48	7358
	Foliar zinc	152	1343	33	6955
Lime	No zinc	179	1571	30	7056
	Soil zinc	119	1199	25	6602
	Foliar zinc	150	1371	41	7106
LSD _{.05}		ns ^a	ns	ns	ns
C.V.%		32.5	20.0	55.1	11.6

^aMeans were not significantly different at the 0.05 level.

Growth and Yield

Cultivar, Zn, and lime treatments did not significantly effect tillering, panicle development, or seed weight. The only significant differences in rice yield were due to cultivar selections.

Conclusions

After two growing seasons, soil pH in plots with lime treatments was elevated to 7.2. Extractable soil Zn levels were lower in limed plots that received soil applied ZnSO₄ fertilizer than unlimed plots with ZnSO₄. This indicates that elevated soil pH may be antagonistic towards extractable Zn levels. However, liming did not significantly reduce Zn plant uptake or the growth and development of rice on this soil. We attribute this lack of response to the high native levels of Zn released in the soil. High tissue levels of Mn may have inhibited the luxury uptake of Zn. Certainly the high Mn levels did not induce a Zn deficiency.

The effect of cultivars on Zn uptake was evident in 1999. Tissue tests showed that Drew and Kaybonnet cultivars were more efficient than Cypress in taking up soil applied ZnSO₄. This may be because these cultivars have better root systems for taking up nutrients including nitrogen. Missouri pre-flood nitrogen recommendations for Drew and Kaybonnet are 84 kg N ha⁻¹

compared to recommended rate of 101 kg N ha⁻¹ for Cypress. We did not observe the Zn deficiency symptoms in rice in this study that are sometimes found in farmer's fields. If soil pH values had increased to near 8.2, Zn deficiency would have been more likely. Based on the results of this test, we recommend that if a field has a history of Zn deficiency that a farmer soil apply ZnSO₄ fertilizer and plant one of the newer cultivars.

References

- Barbosa, F., N. Fageria, O. Silva, A. Barboa, and O. Da Silva. 1992. Interactions between liming and zinc on nutrient uptake and yield of upland rice in the greenhouse. *Revista Brasileira de Ciencia do Solo*. 16:355-360.
- Garrett, J., F. Allgood, B. Brown, R. Grossman, and C. Scrivner. 1978. Soils of the Southeast Missouri Lowlands-major types, fertility, and yield information for soils found in the lowlands of the Bootheel area. Univ. of Missouri-Extension Circular 922.
- Mills, H. and J. Jones. 1996. Agronomic and plantation crops- Interpretative values (*Oryza sativa*) p. 189. (ed.) H. Mills and J. Jones. Plant analysis handbook II. MicroMacro Publishing, Inc., Athens, GA.
- Minor, H., and G. Stafford. 1998. Missouri rice variety performance trials. 1997. p. 7-9. In G. Stevens (ed.) Missouri Rice Research Update. Univ. of Missouri Special Report 98-1.
- Ntamungiro, S., N. Slaton, C. Wilson, M. Daniels, J. Robinson, L. Ashlock, and T. Windham. 1999. Effects of lime, phosphorus, and zinc application on rice and soybean production. Univ. of Arkansas Agric. Exp. Sta. Res. Series. 468:268-276.
- Sajwan, K.S., and W.L. Lindsay. 1986. Effects of redox and zinc deficiency in paddy rice. *Soil Sci. Soc. Am. J.* 50:1264-1269.
- SAS Institute. 1990. SAS/STAT guide for personal computers. Version 6.0. SAS Inst. Cary, N.C.
- Slaton, N., S. Ntamungiro, S. Wilson, and R. Norman. 1999. Evaluation of granular and foliar zinc sources in rice. Univ. of Arkansas Agric. Exp. Sta. Res. Series. 468:291-297.
- Tisdale, S.L., W.L. Nelson, and J.D. Beaton. 1985. Soil fertility and fertilizers. MacMillan Publishing Company, New York.
- Tracy, P. and S. Hefner. 1991. Calculating crop nutrient value from irrigation inputs: a survey of Southeast Missouri irrigation. Univ. of Missouri- Columbia Ext. Water Quality Bull. WQ278.
- Wells, B., B. Huey, R. Norman, and R. Helms. 1993. Rice deficiency symptoms-zinc. p. 16. In W. Bennett (ed.) Nutrient deficiencies and toxicities in crop plants. APS Press. Am. Phytopathological Soc., St. Paul, MN.

Table 3. Mean effect of lime and zinc applications on rice plant nutrient concentrations at internode elongation growth stage and yield in 1999.

Cultivar	Zinc Application	Fe	Mn	Zn	Rice Yield
		mg kg ⁻¹	mg kg ⁻¹	mg kg ⁻¹	kg ha ⁻¹
<u>Cypress</u>					
No Lime	No zinc	212	1104	54	7610
	Soil zinc	256	1107	49	6703
	Foliar zinc	235	1261	58	7157
Lime	No zinc	256	1269	55	7006
	Soil zinc	274	1242	58	7358
	Foliar zinc	208	1182	46	7308
<u>Kaybonnet</u>					
No Lime	No zinc	223	1167	48	7358
	Soil zinc	280	1231	65	7358
	Foliar zinc	222	1132	41	7711
Lime	No zinc	208	977	46	7661
	Soil zinc	184	1250	61	6552
	Foliar zinc	271	1181	53	6955
<u>Drew</u>					
No Lime	No zinc	304	1126	44	7711
	Soil zinc	197	1384	63	7006
	Foliar zinc	310	1374	53	7610
Lime	No zinc	244	1468	52	7157
	Soil zinc	237	1269	66	6955
	Foliar zinc	195	1131	54	7358
LSD _{.05} (comparisons within cultivars)		ns ^a	ns	16	ns
C.V.%		29.0	16.0	20.0	6.4

^aMeans were not significantly different at the 0.05 level. Analysis of variance showed a significant interaction between cultivar and zinc fertilizer for plant zinc concentration.

Hydrolysis of *p*-Nitrophenyl Acetate: Estimation of Rate Enhancement By Various Catalysts

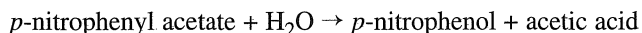
Debra Nzioka and Allen Scism¹

Department of Chemistry, Central Missouri State University, Warrensburg, Missouri 64093

Abstract: The rate enhancement of the hydrolysis of *p*-nitrophenyl acetate (PNPA) by seven catalysts, four amino acids and three enzymes, was determined at pH 7.0 and pH 8.0. All seven catalysts showed significant rate enhancement at both pH values. The enzymes, chymotrypsin, trypsin, and lysozyme, exhibited rate enhancement values greater by several orders of magnitude than those of the individual amino acids, serine, histidine, tyrosine, and lysine. Slight differences were noted in rate enhancement at the two different pH values, but the relative order of effectiveness among the seven catalysts was not changed.

Key Words: Enzymes, *p*-nitrophenyl acetate, chymotrypsin, trypsin, lysozyme, catalysis, rate enhancement, guanidine hydrochloride, denaturation

Hydrolysis of *p*-nitrophenyl acetate (PNPA) to produce *p*-nitrophenol and acetic acid occurs readily.



At neutral or slightly basic pH, *p*-nitrophenoxide ion (PNP) is produced, the absorbance of which can be measured in the visible region of the spectrum by simple spectrophotometers. The extent of hydrolysis of PNPA with time can thus be readily determined by measurement of PNP production.

PNPA has been used as a substrate in kinetic studies of several enzymes including bovine carbonic anhydrase II, α -chymotrypsin, and acetylcholine esterase (1). Head, et. al used PNPA in studies of the catalytic effectiveness of several enzymes and other catalysts at pH 7.0 (5). We have extended the work of Head, et. al by using additional enzymes and amino acids as catalysts as well as testing their relative effectiveness as catalysts not only at pH 7.0 as Head, et. al had done but also at pH 8.0.

Materials

Buffers were prepared using potassium phosphate, dibasic, I-3252, from the J. T. Baker Chemical Company, and potassium phosphate, monobasic, P-285, from Fisher Scientific Company. *P*-Nitrophenyl acetate, N-8130, trypsin, T-82253, chymotrypsin, C-3142, and lysozyme, L-6876, were purchased from Sigma, St. Louis, MO. Histidine (#17080) was purchased from the United

States Biochemical Corporation and DL-serine (#5688) and L-lysine monohydrochloride (#6467) were purchased from the Nutritional Biochemical Corporation. DL-Tyrosine (#5992) was purchased from Eastman. All reagents were used as received.

Stock solutions of PNPA were prepared to be 8.30×10^{-4} M and those of serine, tyrosine, lysine, and histidine were prepared to be 5.00×10^{-4} M. Stock solutions of trypsin, lysozyme, and chymotrypsin were prepared using 0.0050 g of the solid enzyme per 100 mL of solution. Phosphate buffers of pH 7.0 and 8.0 were prepared to be 0.0500 M.

Method

The procedure of Head, et. al was used to follow the hydrolysis of PNPA by measurement of the absorbance of the test solutions, over time, at 405 nm, using a Fisher Scientific Spectro Master, Model 415 spectrophotometer (5). Table 1 illustrates the preparation of the test solutions from the stock solutions. The absorbance of each solution was measured at 405 nm immediately after preparation and periodically over a 60-minute period at ambient temperature.

Table 1. Composition of Test Solutions

Solution Type	Catalyst Stock, mL	PNPA Stock, mL	Buffer, mL	Total Volume, mL
Control	None	1.0	3.0	4.0
Test Solution	1.0	1.0	2.0	4.0

Results

Table 2 contains data collected for seven catalysts at pH 7.0 and Table 3 contains data collected for the same seven catalysts at pH 8.0. The use of a control solution containing no catalyst is quite necessary since PNPA readily undergoes hydrolysis in aqueous solution, as can be noted from the tabular data. The data reported by Head, et. al was indicated to be typical of their determinations (5). Similarly, we report one set of typical data obtained by the student involved in this project.

¹Corresponding author.

Figure 1 illustrates the progress of hydrolysis of PNPA, catalyzed by four different amino acids at pH 7.0 over the 60-minute test period. Figure 2 illustrates the progress of hydrolysis of PNPA, catalyzed by the same four amino acids, at pH 8.0.

Figure 3 illustrates the progress of PNPA hydrolysis, catalyzed by three different enzymes at pH 7.0. Figure 4 illustrates the progress of hydrolysis of PNPA, catalyzed by the same enzymes at pH 8.0. The graphs illustrated in Figures 1-4 were generated using Quattro Pro. The graphed data were not linearly transformed in order to show typical deviation of data points from linearity. Quattro Pro can, however, be used to fit the data to a least squares line.

Table 2. Absorbance of Test Solutions @ 405 nm at pH 7.0

Time, min	0	5	10	15	20	25	35	45	60
Control	0.0482	0.0506	0.0555	0.0580	0.1024	0.1249	0.1838	0.2147	0.2518
Tyrosine	0.0506	0.0605	0.0680	0.1079	0.1135	0.1367	0.2076	0.2366	0.2716
Histidine	0.0531	0.0655	0.0731	0.1192	0.1279	0.1805	0.2111	0.2480	0.2924
Lysine	0.0555	0.0706	0.0996	0.1296	0.1561	0.1904	0.2549	0.2840	0.3098
Serine	0.0706	0.0809	0.1163	0.1612	0.1858	0.2218	0.2757	0.3054	0.3279
Chymotrypsin	0.2007	0.2255	0.2924	0.3372	0.3615	0.4437	0.4881	0.5686	0.6198
Lysozyme	0.1612	0.1772	0.2403	0.2557	0.3054	0.3468	0.4202	0.4815	0.5376
Trypsin	0.2111	0.2403	0.3188	0.3872	0.4034	0.4815	0.5302	0.5935	0.6576

Table 3. Absorbance of Test Solutions @ 405 nm at pH 8.0

Time, Min	0	5	10	15	20	25	35	45	60
Control	0.0410	0.0506	0.0555	0.0731	0.1024	0.1163	0.1427	0.1805	0.2007
Tyrosine	0.0842	0.0555	0.0580	0.0783	0.1079	0.1278	0.1457	0.1871	0.2291
Histidine	0.0506	0.0605	0.0703	0.0915	0.1107	0.1367	0.1612	0.1904	0.2366
Lysine	0.0531	0.0610	0.0742	0.0996	0.1249	0.1487	0.1925	0.2366	0.2557
Serine	0.0630	0.0706	0.0862	0.1135	0.1427	0.1707	0.2147	0.2480	0.2924
Chymotrypsin	0.1192	0.1278	0.1397	0.1612	0.1772	0.2518	0.3098	0.3420	0.4318
Lysozyme	0.0996	0.1079	0.1135	0.1278	0.1487	0.1643	0.2366	0.3143	0.4089
Trypsin	0.1308	0.1367	0.1487	0.1739	0.2007	0.2676	0.3372	0.3872	0.4498

Discussion

To better compare the effectiveness of the seven different catalysts used in the PNPA hydrolysis experiments, a rate enhancement (R.E.) value was calculated for each. The rate enhancement is the change in absorbance, with respect to the control, per minute, per mole of the catalyst in the assay solution. Units are $\text{min}^{-1}\text{mol}^{-1}$.

$$\text{R. E.} = \frac{\text{Rate}_{\text{catalyst}} - \text{Rate}_{\text{control}}}{\text{Moles of catalyst}}$$

The rate of reaction is reflected by the increase in absorbance of the test solutions per minute, which is due to the production of PNP as hydrolysis of PNPA occurs. Since change in absorbance per minute is the slope of each individual line on the graphs, the Quattro Pro program was used to obtain the slope of each line by means of regression analysis.

For example, 1.0 mL of the 5.00×10^{-4} M histidine stock solution was mixed with 2.0 mL of buffer and 1.0 mL of PNPA stock solution. The resulting test solution therefore contained 5.0×10^{-7} mol of histidine. Regression analysis of the pH 7.0 data indicated a slope for the control of $0.0038896 \text{ min}^{-1}$ and a slope for the histidine data of $0.004294 \text{ min}^{-1}$. The rate enhancement for histidine, then, is:

$$\text{R. E.} = \frac{(0.004294 - 0.0038896) \text{ min}^{-1}}{5.00 \times 10^{-7} \text{ mol}} = 809 \text{ min}^{-1}\text{mol}^{-1}$$

The moles of enzyme in the assay solutions were calculated using molar masses of 21,600 for chymotrypsin, 14,300 for lysozyme, and 23,800 for trypsin (8, 2, 3). Different sources report somewhat different values for the molar masses of enzymes, but the rate enhancement values should not be drastically altered by slightly different molar masses.

Table 4 shows rate enhancement values calculated for the seven catalysts at pH 7.0, while Table 5 shows rate enhancement values for those same catalysts at pH 8.0.

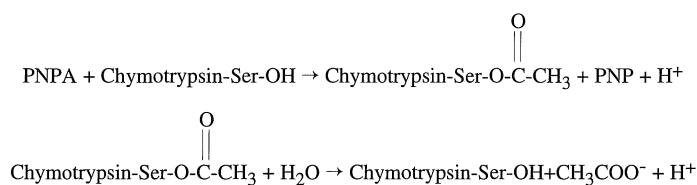
From the data in Tables 1 and 2 and the graphs illustrated in Figures 1 and 2, it appears that all four amino acids exerted a catalytic effect in the hydrolysis of PNPA. Serine was most effective of the four amino acid catalysts and tyrosine was least effective. The relative order of effectiveness of these catalysts was the same at pH 8.0 as it was at pH 7.0. The rate enhancement values shown in Tables 4 and 5 indicate that tyrosine and histidine were less effective at pH 8.0 than at pH 7.0. Lysine and serine, however, appear to be more effective at the higher pH.

From the data in Tables 1 and 2 and the graphs illustrated in Figures 3 and 4, one may note that all three enzymes are better catalysts for the hydrolysis of PNPA than are any of the four amino acids used. Chymotrypsin and trypsin showed the greatest enhancement of catalytic activity. At pH 8.0, the catalytic activity was somewhat decreased compared to that at pH 7.0, but the relative order of catalytic effectiveness of the three enzymes was not altered. The decrease in activity at pH 8.0 may be due to alteration of the conformation of the enzymes such that the active site of the enzymes is less accessible by the PNPA substrate.

In an attempt to compare values of rate enhancement determined in this study to those of Head, et. al, it was noted that the

values reported by Head, et. al must be multiplied by 10^3 (2). This was determined by using their data and calculating rate enhancement in units of $\text{min}^{-1}\text{mol}^{-1}$. Thus, their value of $1.70 \text{ min}^{-1}\text{mol}^{-1}$ for the rate enhancement of the amino acid serine is really $1.70 \times 10^3 \text{ min}^{-1}\text{mol}^{-1}$. This compares well to the value of $1.682 \times 10^3 \text{ min}^{-1}\text{mol}^{-1}$ determined for serine in this study. The value of $3.348 \times 10^3 \text{ min}^{-1}\text{mol}^{-1}$ found by Head, et. al for the rate enhancement of chymotrypsin is really $3.348 \times 10^6 \text{ min}^{-1}\text{mol}^{-1}$ and is the same order of magnitude as the value of $1.51 \times 10^6 \text{ min}^{-1}\text{mol}^{-1}$ determined in this study. There are several factors that may not allow exact duplication of the values reported by Head, et. al. Head and coworkers did not report the temperature at which their determinations were made so one must assume they were made at room temperature. It is possible that temperatures were somewhat different in their Manchester laboratory than those in our laboratory. Additionally, it is uncertain that the purity of the catalysts used in both studies were identical. As indicated elsewhere in this paper, some differences may exist in the molar masses used for various enzymes in calculations of rate enhancement values.

Trypsin and chymotrypsin are serine proteases that have been shown to follow a Ping Pong Bi Bi catalytic mechanism (4, 6, 7). During the catalysis of the hydrolysis of PNPA, an active site serine residue of chymotrypsin is acylated, with the release of PNP, followed by release of the acetate group from the acyl-enzyme intermediate due to the action of the second substrate, water. The latter step is rate-determining.



One might speculate that lower $[\text{H}^+]$, that is, higher pH, might serve to help drive these steps of the mechanism, but that is not reflected by the decreased hydrolysis noted at pH 8.0 compared to that at pH 7.0. Alteration of the enzyme to a slightly less active conformation may be a more likely cause.

Although lysozyme shows noticeable catalytic activity in the hydrolysis of PNPA, it is the least effective of the three enzymes tested. It is considerably more effective than any of the four amino acids tested, however. While lysozyme is a hydrolase, its normal substrate is neither an ester nor a protein, but the glycosidic linkages of N-acetylmuramic acid (NAM) that is linked to N-acetylglucosamine (NAG) in bacterial cell walls. (8) Serine residues are not thought to be involved in the active site binding and catalysis by lysozyme.

Table 4. Rate Enhancement Values for Various Catalysts at pH 7.0

Catalyst	Regression Slope, min^{-1}	Moles of Catalyst in the Test Solution	Rate Enhancement, $\text{min}^{-1} \text{mol}^{-1}$
Control	0.0038896		
Tyrosine	0.004067716	5.00×10^{-7}	356
Histidine	0.004294	5.00×10^{-7}	809
Lysine	0.0046699	5.00×10^{-7}	1561
Serine	0.004730683	5.00×10^{-7}	1682
Chymotrypsin	0.007376	2.31×10^{-9}	1.51×10^6
Lysozyme	0.006843	3.50×10^{-9}	0.844×10^6
Trypsin	0.007667	2.10×10^{-9}	1.80×10^6

Table 5. Rate Enhancement Values for Various Catalysts at pH 8.0

Catalyst	Regression Slope, min^{-1}	Moles of Catalyst in the Test Solution	Rate Enhancement, $\text{min}^{-1} \text{mol}^{-1}$
Control	0.00292		
Tyrosine	0.002915	5.00×10^{-7}	-10
Histidine	0.003216	5.00×10^{-7}	592
Lysine	0.003791	5.00×10^{-7}	1742
Serine	0.004134	5.00×10^{-7}	2428
Chymotrypsin	0.005572	2.31×10^{-9}	1.15×10^6
Lysozyme	0.005343	3.50×10^{-9}	0.692×10^6
Trypsin	0.005945	2.10×10^{-9}	1.44×10^6

Conclusion

Anderson, et. al, and Head, et. al have indicated that the study of the catalytic hydrolysis of *p*-nitrophenyl acetate has been the basis for a number of projects by students. (1, 5) We agree that these kinds of studies can make interesting projects for students and have used them as such for the past two years. We have extended the studies of Head, et. al by using different amino acids as well as other hydrolytic enzymes at two different pH values, 7.0 and 8.0. While all seven catalysts showed significant rate enhancement, the enzymes were the most effective. Of the enzymes, the serine proteases were the most effective in catalyzing hydrolysis of PNPA. Of the four amino acids used as catalysts, serine was the most effective at both pH values.

The most significant feature of the procedure is that it allows direct comparison of the catalytic effectiveness of potential cata-

lysts. Comparisons must be made under the same set of conditions, with a control used with each set of test solutions. It seems possible that such studies could also be adapted and used as a specific experiment in the biochemistry laboratory rather than as a full semester project. Preparation of test solutions prior to the laboratory period would allow laboratory time to be used for data collection. Data analysis and preparation of reports could be done out of class.

Literature Cited

1. Anderson, J., Byrne, T., Woelfel, K. J., Meany, J. E., Spyridis, G. T., and Pocker, Y., *J. Chem. Educ.* 1994, 71, 715-718.
2. Head, Michael B., Mistry, Kalpna S., Ridings, Bernard J., and Smith, Christopher A., *J. Chem. Educ.* 1995, 72, 184-186.

3. Horton, Robert H., Moran, Laurence A., Ochs, Raymond S., Rawn, J. David, and Scrimgeour, K. Gray, *Principles of Biochemistry*, Neil Patterson Publishers/Prentice-Hall, Inc. Englewood Cliffs, NJ, 1993, p 5.16.
4. Hartley, B. S., and Kilby, B. A., *Biochem. J.* 1954, 56, 294.
5. Voet, Donald, and Voet, Judith G., *Biochemistry*, John Wiley & Sons, New York, 1990, pp. 373-375.
6. Voet, Donald, Voet, Judith G., and Pratt, Charlotte W., *Fundamentals of Biochemistry*, John Wiley & Sons, Inc., New York, 1999, pp. 300-307.
7. *Biochemicals and Reagents for Life Science Research*, Sigma-Aldrich Co., St. Louis, MO, 2000, p.1988.
8. Dixon, Malcolm, and Webb, Edwin C., *Enzymes*, Academic Press, Inc., New York, 1964, p. 453.

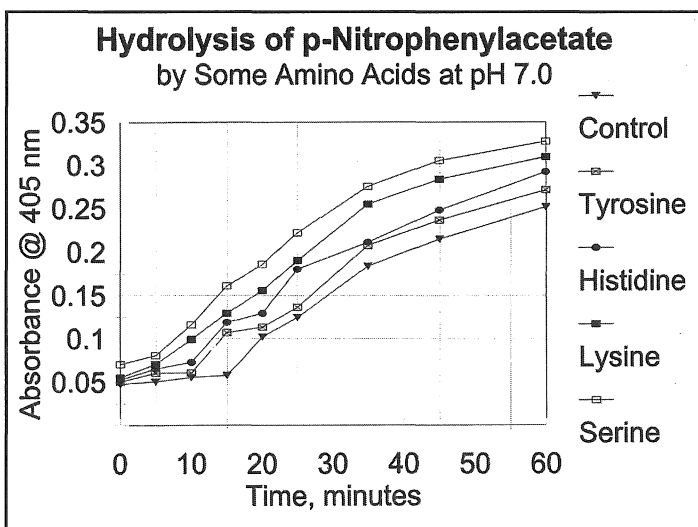


Figure 1. Hydrolysis of *p*-Nitrophenyl Acetate at pH 7.0, Catalyzed by Amino Acids

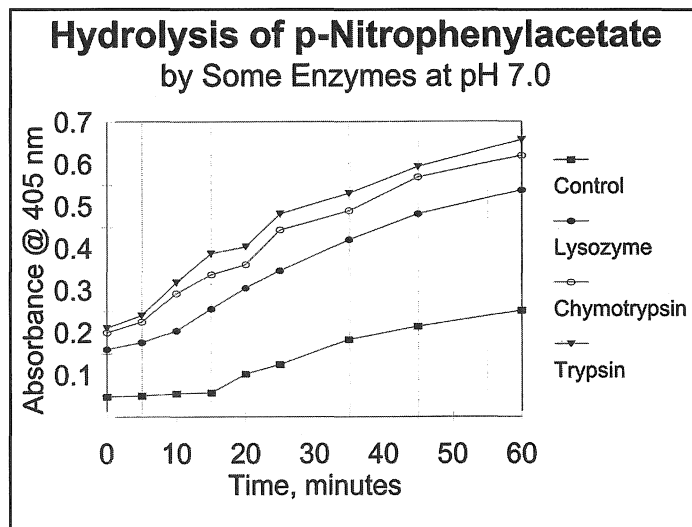


Figure 3. Hydrolysis of *p*-Nitrophenyl Acetate at pH 7.0, Catalyzed by Enzymes

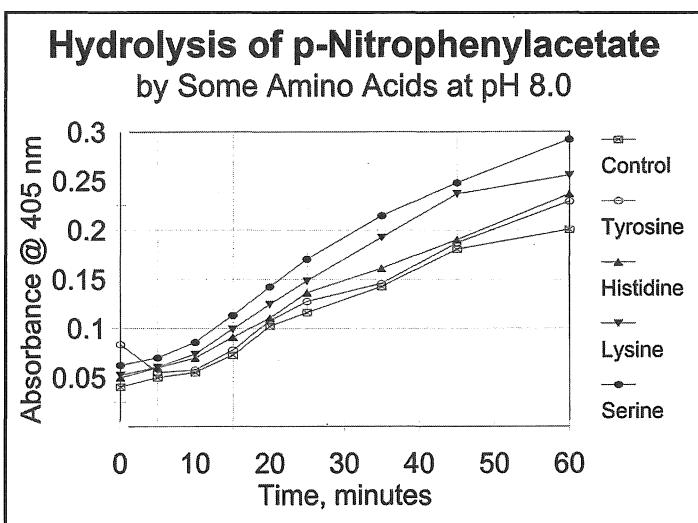


Figure 2. Hydrolysis of *p*-Nitrophenyl Acetate at pH 8.0, Catalyzed by Amino Acids

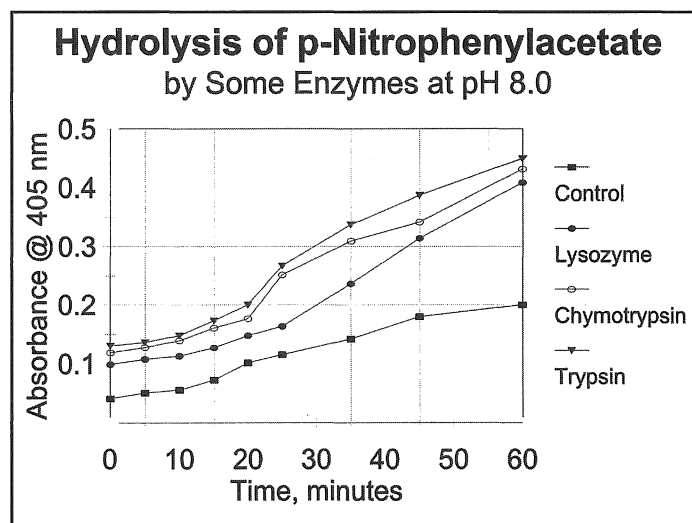


Figure 4. Hydrolysis of *p*-Nitrophenyl Acetate at pH 8.0, Catalyzed by Enzymes

An Evaluation of an Experimental And a Deepwater Benthic Fish Trap In a Large River System

Jason W. Crites, Valerie A. Barko, and Robert A. Hrabik

Missouri Department of Conservation, Fisheries Research, Assessment, and Monitoring Section
Open River Field Station, 3815 East Jackson Boulevard, Jackson, Missouri 63755

Abstract: Open River Field Station (ORFS) staff developed the Missouri trawl to capture small benthic fishes (e.g. *Macrhybopsis* spp.) in deep, swift areas of the Mississippi River. However, it was not possible to determine exactly where fish were caught during a trawl haul, thus it was difficult to describe microhabitats used by these fishes. The ORFS staff designed an experimental passive gear to capture benthic fishes in deep and swift water to better quantify microhabitat areas used by these fish. A modified mini-fyke net was used in conjunction with the experimental net for comparison. The nets were set in pairs within two habitat areas (i.e., main channel border and main channel border wing-dam). The experimental net captured a total of 121 fish and 1 Ohio Shrimp, *Macrobrachium ohione*. The modified mini-fyke net captured 126 fish and 1 *M. ohione*. There was no overall significant difference in catch rates between the two gears.

Key Words: *Macrhybopsis*, mini-fyke net, fishing gear, *Macrobrachium ohione*, passive gear, Mississippi River, wing dike.

Introduction

The Sicklefin Chub, *Macrhybopsis meeki*, and Sturgeon Chub, *Macrhybopsis gelida*, are listed as rare and uncommon in Missouri (MNHP, 2001). The decline in distribution and relative abundance of these chubs prompted the U.S. Fish and Wildlife Service (USFWS) to elevate these species to candidates for listing under the Endangered Species Act. However, they were not listed (see USFWS, 2001). *M. gelida* are thought to be a generalist species that tolerate a wide variety of habitat conditions (Young, 1997). However, Pflieger (1997) suggests *M. gelida* are confined to open channels of large rivers, preferring a strong current with sand and fine gravel substrate. Similarly, Pflieger (1997) states that *M. meeki* are confined to the main channels of large, turbid rivers, living in strong current over sand or fine gravel substrate. *M. meeki* are likely adapted to deep, swift water that often exceed 1 m/s and is > 3 m in depth (Young, 1997).

Open River Field Station (ORFS) staff used various methods to sample *Macrhybopsis* spp. and other benthic species including trawling, electrofishing, seining, and mini-fyke netting. While some of these methods were effective along the shoreline of the

Mississippi River, only trawling was applicable to the main river channel where most *Macrhybopsis* spp. were found (ORFS, unpubl. data). Unfortunately, it was difficult to determine where a fish was captured along a trawl haul. Standard trawl hauls used by ORFS staff were 350 m long (Gutreuter et al., 1995). ORFS staff wanted to design a stationary net that could be set in deep, swift water to better assess microhabitat use of *Macrhybopsis* spp. and other benthic fishes.

Gryska et al., (1998) designed a passive trap net to catch Kendall Warm Springs Dace, *Rhinichthys osculus thermalis*, a fish that lives in small streams. We modified their net (henceforth called the experimental net) by making it larger and sturdier to withstand the harsh environment of the Middle Mississippi River (MMR; that portion of the Mississippi River between the confluences of the Missouri and Ohio rivers). Although the experimental net was rigid and designed for deep, swift water, it could also be fished in areas of little or no water velocity. ORFS staff preferred setting this type of passive gear because it could be handled without mechanized assistance, other than a boat, and it required little specialized training to operate (Hubert, 1996).

The objectives of this study were to compare the number of fish captured between the two net types to determine the usefulness of the experimental net in the MMR and describe microhabitat used by *Macrhybopsis* spp.

Methods

This study was conducted between MMR kilometers 48.3 to 128.7 (Fig. 1). Sampling was conducted from June-November 2000. Sites were selected subjectively to minimize net loss, maximize catch, and focus on deepwater habitats in wing dike (MCBW) and along the main channel border (MCBU) unstructured habitat (see Wilcox, 1993).

The experimental net consisted of a 0.95 cm steel rod frame and measured 107.9 cm wide, 30.4 cm high, and 152.4 cm long. The bottom of the frame was curved upward to give it a fusiform shape so the net would not be buried in the substrate or lost because of high velocity flows. This shape also decreased drag on the net. The experimental net was wrapped with 0.32 cm Ace style mesh. The entrance of the experimental net was V-shaped following Gryska and Hubert (1998) with an aperture diameter of

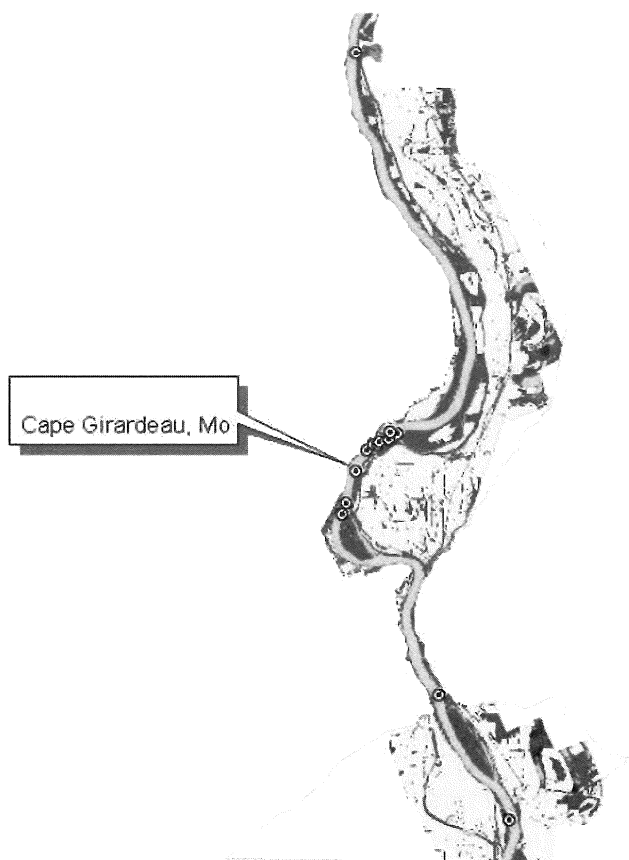


Figure 1. Map of the Middle Mississippi River. Sites are identified by white dots throughout the reach

5 cm that was fixed using a stainless-steel ring following Gutreuter et. al. (1995). At the opposite end, a rope was sewn to the cod end mesh to support the throat to make a more durable and accessible catch chamber and to create a closing mechanism to seal the cod end (Fig. 2).

ORFS staff modified the mini-fyke net by removing the lead from the cab to make it more applicable for deepwater sets. Typically, this lead acted as a fence that was anchored on the shore to guide fish into the cab of the trap net. It was removed because it was impractical to use in main channel deepwater habitats. The net dimensions of the cab were 94.0 cm wide, 33.0 cm high, and 27.9 cm deep. The cod end measured 203.2 cm deep with a ring diameter of 38.1 cm. One throat was attached to the first hoop with an aperture diameter of 5 cm and was fixed using a stainless-steel ring (Gutreuter et. al. 1995). The modified mini-fyke was covered with 0.32 cm Ace style mesh (Fig. 3). The modified mini-fyke was collapsible and needed flow to hold the trap open. The mesh used on both nets was green dipped to protect it from deteriorating. Green dip is a water based latex dip used for coating netting.

A single set included both the experimental net and the modified mini-fyke net (paired set). These nets were set in close proximity to each other at each site and were anchored separately. Nets were set parallel to the shore by first anchoring a rope 15.2 to 30.5 m from the shoreline to a rock bag or cab weight. A rope was attached from the rock bag or cab weight to the net extend-

ing parallel to the shore. The nets were fished for 24 hours.

Water physical data were measured at each site, which included water depth (m), surface water velocity (m/s), substrate, secchi disc transparency (cm), and water temperature ($^{\circ}\text{C}$). Predominant substrate type was determined at each site to further describe the habitat where *Macrhybopsis* spp. were captured. Chi-square analyses were used to test for differences ($P \leq 0.05$) in fish abundance (i.e. total number of individuals) between paired net sets (Steel and Torrie, 1980).

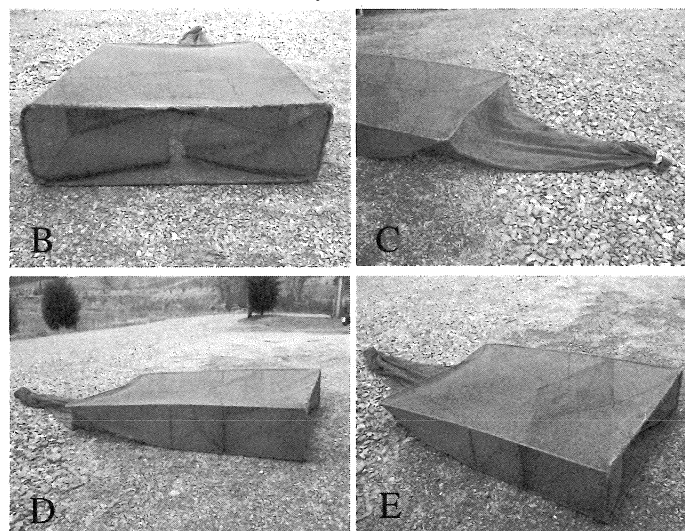
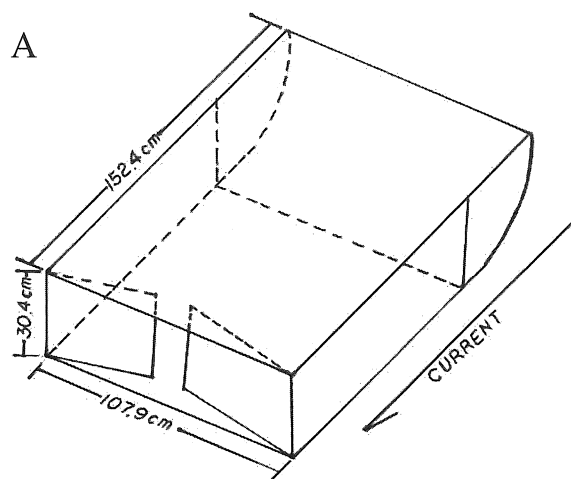


Figure 2. Drawing and photographs of experimental net. (A) Drawn dimensions of net. (B) Front cab view. (C) Rear cod view. (D) Side view. (E) Top View.

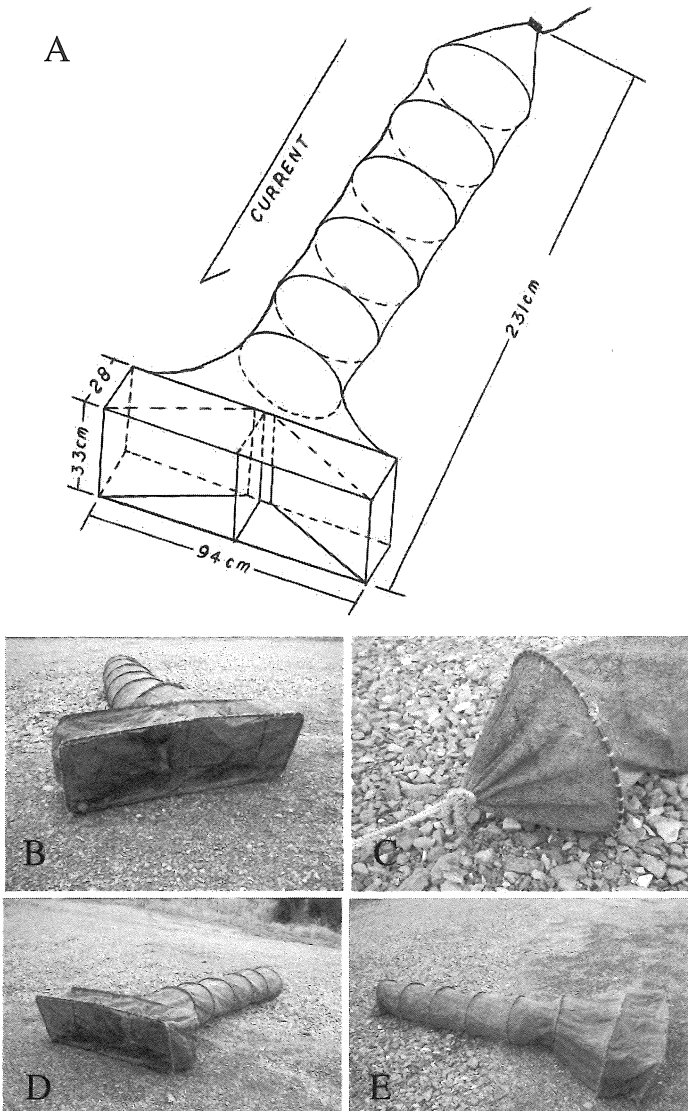


Figure 3. Drawing and photographs of modified mini-fyke net. (A) Drawn dimensions of net. (B) Front cab view. (C) Rear cod view. (D) Side view. (E) Top view.

Results

A total of 19 paired sets were completed. Sixteen of the 19 sets were in MCBU and 3 were below MCBW. The MCBU sets consisted of 4 gravel substrate sets, 7 sand substrate sets, and 5 silt/sand substrate sets. The MCBW sets consisted of 3 sand substrate sets. Secchi visibility ranged from 17 to 48 cm (mean = 29 cm), depth ranged from 0.9 to 7.5 m (mean = 2.9 m), surface water velocity ranged from 0.10 to 0.70 m/s (mean = 0.31 m/s), and water temperature ranged from 4.1 to 29.5°C (mean = 26.1°C, see Table 1).

The modified mini-fyke captured 126 fish while 121 fish were captured in the experimental net (Table 2). One Ohio Shrimp, *M. ohione*, was captured in each net type. Because of the small sample size, *M. ohione* data was not included in the statistical analysis. *Macrhybopsis* spp. chubs were not captured in either net. The modified mini-fyke net caught 11 species and the experi-

mental net caught 9 species (Table 2). Channel Catfish, *Ictalurus punctatus*, dominated the catch in both nets. *I. punctatus* composed 87.4% of the catch in the modified mini-fyke net and 66.4% in the experimental net. No significant difference between fish abundance and net-type were detected ($X^2 = 0.101, P > 0.75$).

Table 1. Water physical measurements of sites sampled using experimental and modified mini fyke nets.

Site	Secchi (cm)	Depth (m)	Velocity (m/s)	Substrate	Temperature (°C)	utm Easting	utm Northing
1	18	6.0	0.35	Sand	28.1	810089	4136226
2	24	3.0	0.23	Silt/Sand	26.8	807446	4164116
3	40	7.5	*	Silt/Sand	28.1	808801	4132393
4	39	2.0	0.65	Sand	28.1	808613	4131673
5	35	1.0	0.12	Sand	28.6	811178	4137061
6	27	1.0	0.70	Gravel	28.5	812056	4137484
7	29	3.0	0.22	Sand	28.6	810550	4136742
8	30	7.5	0.21	Silt/Sand	29.3	809342	4134691
9	34	6.0	0.39	Silt/Sand	29.2	816228	4119337
10	28	1.0	0.38	Sand	29.1	821811	4110872
11	26	0.9	0.35	Sand	29.5	821811	4110817
12	23	0.9	0.60	Sand	29.0	810539	4136655
13	17	1.8	0.21	Gravel	29.3	812084	4137549
14	19	1.8	0.16	Sand	28.9	808608	4131576
15	30	2.1	0.20	Silt/Sand	25.0	808786	4132342
16	34	3.0	0.17	Sand	25.4	810811	4136647
17	24	3.0	0.25	Sand	20.0	810925	4136876
18	26	2.1	0.10	Gravel	21.2	811576	4137055
19	48	1.6	*	Gravel	4.1	811605	4137542

*velocity readings were unobtainable

Discussion

Although both nets caught fish, neither captured *Macrhybopsis* spp. This may be because the nets created a velocity break that *Macrhybopsis* spp. may not seek. Pflieger (1997) suggested that both *M. gelida*, and *M. meeki* prefer strong currents, which suggests they may avoid velocity breaks. Conversely, chubs could have avoided the nets. However, this was unlikely because the MMR is very turbid and does not allow light to penetrate very far below the surface. One way to lessen the magnitude of the velocity break and possibly increase chub capture would be to use a larger mesh. A larger mesh size would also reduce drag on the nets (Dickson, 1962). However, *Macrhybopsis* spp. chubs are small fish and an increase in mesh size may allow escapement.

The lack of chubs in the samples may also be related to temporal habits. Dettmers et al. (2001) suggested that there are numerous behavioral cues that may influence the locations and seasons that fishes use the main channel. Therefore, variables such as river stage height and time of year may affect the location and movement of fishes. *Macrhybopsis* spp. are thought to be early spring spawners and may not have been active in summer when we conducted this study (Pflieger, 1997).

The capture of *M. ohione* is important because this shrimp is rare in the MMR and techniques have not yet been developed to adequately sample this species. Conaway and Hrabik (1997) found that of 1,114 shrimp collected in 1992 only 4 were *M. ohione*, three of which were collected from wing dikes. ORFS

Table 2. Catch and relative abundance of fishes and *Macrobrachium ohione* by gear and substrate type in the Middle Mississippi River from June-November 2001.

	number	relative abundance	Sand	Silt/Sand	Gravel
Modified mini-fyke net					
Bluegill, <i>Lepomis macrochirus</i>	2	1.6%	2 (100.0%)		
Channel catfish, <i>Ictalurus punctatus</i>	111	87.4%	73 (65.8%)	3 (31.5%)	3 (2.7%)
Channel shiner, <i>Notropis wickliffi</i>	1	0.8%	1 (100.0%)		
Emerald shiner, <i>Notropis atherinoides</i>	1	0.8%	1 (100.0%)		
Flathed catfish, <i>Pylodictis olivaris</i>	2	1.6%	2 (100.0%)		
Freckled madtom, <i>Noturus nocturnus</i>	2	1.6%		2 (100.0%)	
Freshwater drum, <i>Aplodinotus grunniens</i>	4	3.2%	4 (100.0%)		
Ohio shrimp, <i>Macrobrachium ohione</i>	1	0.8%	1 (100.0%)		
Striped bass, <i>Morone saxatilis</i>	1	0.8%	1 (100.0%)		
Stonecat, <i>Noturus flavus</i>	1	0.8%		1 (100.0%)	
White bass, <i>Morone chrysops</i>	1	0.8%	1 (100.0%)		
Total	127	100.0%			
Experimental net					
Blue catfish, <i>Ictalurus furcatus</i>	3	2.5%	2 (66.7%)	1 (33.3%)	
Channel catfish, <i>Ictalurus punctatus</i>	81	66.4%	40 (49.4%)	11 (13.6%)	30 (37.0%)
Channel shiner, <i>Notropis wickliffi</i>	1	0.8%	1 (100.0%)		
Flathed catfish, <i>Pylodictis olivaris</i>	3	2.5%	3 (100.0%)		
Freckled madtom, <i>Noturus nocturnus</i>	4	3.3%	2 (50.0%)	1 (25.0%)	1 (25.0%)
Freshwater drum, <i>Aplodinotus grunniens</i>	25	20.5%	13 (52.0%)	9 (36.0%)	3 (12.0%)
Ohio shrimp, <i>Macrobrachium ohione</i>	1	0.8%		1 (100.0%)	
Red shiner, <i>Cyprinella lutrensis</i>	1	0.8%	1 (100.0%)		
Stonecat, <i>Noturus flavus</i>	3	2.5%	3 (100.0%)		
Total	122	100.0%			

biologists have captured 208 *M. ohione* from 1993 thru 2000, 35 of which were collected within MCBW habitat (ORFS, unpubl. data). One *M. ohione* captured in this study was collected from wing dike habitat.

Because the experimental net did not capture *Macrhybopsis* spp., ORFS staff could not assess microhabitat use. Further research is needed in developing a passive gear that will sample litho-psammophilic fishes that avoid crevice habitat.

Acknowledgements

Funding for this project was provided, in part, by the U. S. Fish and Wildlife Service, Endangered Species Act, Section 6 Program, Agreement Number E-1-37. Fieldwork was made possible with assistance by D. P. Herzog, D. E. Ostendorf, J. W. Ridings, L. Evans, C. Beachum, and W. Dunker. Illustrations were provided by D.E. Ostendorf. Thanks to the anonymous reviewers for taking time and effort to look over this manuscript.

Literature Cited

- Conaway, L.K. and R.A. Hrabik. 1997. The Ohio Shrimp, *Macrobrachium ohione*, in the Upper Mississippi River. Transactions Missouri Academy of Science. 31: 44-46.
- Dettmers, J.M., S. Gutreuter, D.H. Wahl, and D.A. Soluk. 2001. Patterns in abundance of fishes in main channels of the upper Mississippi River system. Canadian Journal of Fishery Aquatic Science. 58(5): 933-942.
- Dickson, W. 1962. Modern Fishing Gear of the World. Vol. II Fishing News Books Ltd., London, p. 181.
- Gryska, A.D., W.A. Hubert, and K.G. Gerow. 1998. Relative abundance and lengths of Kendall Warm Springs dace captured from different habitats in a specially designed trap. Transactions of the American Fisheries Society. 127:309-315.
- Gutreuter, S., R. Burkhardt, and K. Lubinski. 1995. Long Term Resource Monitoring Program Procedures: Fish Monitoring. National Biological Service, Environmental Management Technical Center, Onalaska, Wisconsin, July 1995. LTRMP 95-P002-1. 42 pp. + Appendizes A-J.

- Hubert, W.A. 1996. Passive capture Techniques. Pages 157-181 in B.R. Murphy and D.W. Willis, editors. Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.
- Missouri Natural Heritage Program (MNHP). 2001. Missouri species of conservation concern checklist. Missouri Department of Conservation. Jefferson City, Missouri. xi + 28 pp.
- Pflieger, W.L. 1997. The Fishes of Missouri. Conservation Commission of the State of Missouri. Jefferson City, MO. pp.134-136.
- Steel, R.G.D. and J.H. Torrie. 1980. Principles and Procedures of Statistics: A Biometrical Approach, 2nd Edition. McGraw-Hill Inc., New York.
- United States Fish and Wildlife Service (USFWS). 2001. Endangered and Threatened Wildlife and Plants; 12-month Finding for a Petition to list the Sicklefin Chub (*Macrhybopsis meeki*) and the Sturgeon Chub (*Macrhybopsis gelida*) as Endangered. Department of Interior. Federal Register, Vol. 66, No. 75. pp. 19910-19914.
- Wilcox, D.B. 1993. An aquatic habitat classification system for the Upper Mississippi River System. U.S. Fish and Wildlife Service, Environmental Management Technical Center, Onalaska, Wisconsin, May 1993. EMTC 93-T003. 9 pp. + Appendix A. (NTIS # PB93-208981).
- Young, B.A., T.L. Welker, M.L. Wildhaber, C.R. Berry, and D. Scarnecchia, editors. 1997. Population structure and habitat use of benthic fishes along the Missouri and Lower Yellowstone Rivers. 1997 Annual Report of Missouri River Benthic Fish Study PD-95-5832 to the U.S. Army Corps of Engineers and the U.S. Bureau of Reclamation.

Harmonic Oscillator Damped by Sliding Friction

Michael Ottinger

Missouri Western State College, St. Joseph, MO 64507

Mohammad Samiullah, and Ian Lindevald

Truman State University, Kirksville, MO 63501

Corresponding Author:

Dr. Michael B. Ottinger

Computer Science, Mathematics & Physics

Missouri Western State College, 4525 Downs Drive, St. Joseph, MO 64507

Abstract: The motion of a block acted upon by a simple harmonic oscillator (linear spring) and damped by sliding friction is solved exactly. The resulting analysis shows that there are two characteristic parameters that completely determine the motion of the block. This motion is divided into four classifications of oscillation and each is graphically demonstrated. Additional insight is provided through an analysis of the time dependence of the block's mechanical energy. Finally, we discuss the significant differences between the harmonic oscillator damped by friction and the oscillator damped through linear viscous damping.

Introduction

The simple harmonic oscillator damped by sliding friction, as compared to linear viscous friction, provides an important example of a nonlinear system that can be solved exactly. Although this system has been the subject of several articles [1,2,3], we provide some additional insights concerning the analytic solution and its graphical representations.

The system consists of a block with mass m resting on a horizontal surface (See Fig. 1). The block is attached to an immovable wall by a spring with spring constant k . The coefficient of kinetic friction between the block and the horizontal surface is assumed to be constant and will be denoted by μ . Clearly no motion is possible if the initial displacement from equilibrium (x_o) is such that $kx_o \leq \mu_s mg$, where μ_s is the coefficient of static friction. For the sake of the derivation, we will assume that $kx_o > \mu_s mg$ such that we are in the dynamic regime. We also set $\mu_s = \mu$ for simplicity.

Equation of Motion and Its Solutions

The equation of motion for this system is obtained from the horizontal forces acting on the block: the spring restoring force ($-kx$) and the kinetic frictional force ($-\mu mg \frac{\dot{x}(t)}{|\dot{x}(t)|}$). Inserting these forces into Newton's Second Law and solving for the acceleration, yields the equation of motion for the block,

$$\ddot{x}(t) = -\frac{k}{m}x(t) - \mu g \frac{\dot{x}(t)}{|\dot{x}(t)|}. \quad (1)$$

Unlike the differential equation that governs the harmonic oscillator with linear viscous damping, this equation is nonlinear. Never the less, the frictional force is only dependent upon the direction of the velocity. Since the direction is constant between turning points (namely, points where $\dot{x}(t)=0$), Eq. (1) can be solved explicitly between these points. Matching the solutions from each segment produces the general solution.

Introducing the usual definition of angular frequency, $\omega = \sqrt{k/m}$, and dimensionless parameters of $\beta = \frac{\mu mg}{kx_o}$ and $X(t) = \frac{x(t)}{x_o}$, where x_o is a length scale to be identified as the location of the first turning point of $x(t)$ motion, the equation of motion between each turning point can be written as

$$\ddot{X}(t) = -\omega^2(X(t) \mp \beta), \quad (2)$$

where the top sign of the \mp is for segments with positive velocity and the bottom sign is for segments with negative velocity. Equation (2) is solved readily to yield¹

$$X(t) = (X_o \mp \beta) \cos(\omega t) + \frac{V_o}{\omega} \sin(\omega t) \pm \beta, \quad (3)$$

where X_o is the initial location of the block and V_o is its initial velocity in the scaled variable X . Equation (3) tells us that during each time segment the motion of the block is harmonic with constant amplitude whose center of oscillation has been either shifted to the left or to the right of the equilibrium position by an amount β . Equation (3) also shows that the duration of each segment is constant ($\tau = \pi/\omega$) and is independent of the frictional force (i.e., the frictional damping does not affect the oscillation frequency).

If we start with initial velocity V_o equal to zero, then the initial turning point is the initial position of the block, $x_o = \tilde{x}_o$, and can be used as the length scaling factor. For the remainder of the paper

¹This solution is analogous to that of a block oscillating on a spring while under the influence of gravity. The differential equation of motion for that block would be

$$\ddot{x}(t) = -\frac{k}{m}x(t) - g,$$

with solution

$$x(t) = \left(x_o + \frac{mg}{k}\right) \cos\left(\sqrt{\frac{k}{m}}t\right) - \frac{mg}{k}.$$

where x_o is the initial displacement of the block from the unstretched position of the string, and the block is initially stationary. The force of gravity lowers the equilibrium position of the block, but does not alter the oscillation frequency nor amplitude (as measured from the new equilibrium position).

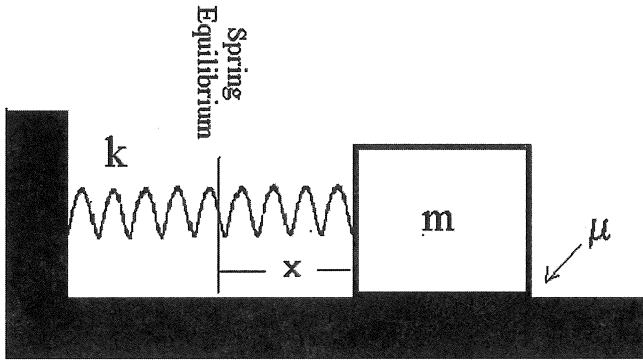


Figure 1. A block undergoes damped oscillation when acted upon by a spring and kinetic friction.

we will consider the initial conditions² such that $V_o=0$, and use x_o in place of \tilde{x}_o . Matching Eq. (3) at the boundary between consecutive segments yields an equation for the relative position of the block over multiple segments

$$X(t) = [1 - (2n + 1)\beta] \text{Cos}(\omega t) + (-1)^n \beta, \tag{4}$$

where n is the number of previously completed cycles, or the integer part of ωt .

It is interesting to note that as the block oscillates, friction decreases its amplitude in steps. This decrease appears in Eq. (4) at the turning points, as the center of oscillation is shifted toward the block by an amount equal to twice β . When, at a turning point, the block is at a distance less than 2β from the previous center of oscillation, the block stops oscillating and remains stationary at that location. Physically, at this point the static friction has become greater than the restoring spring force and thus prevents the block from moving. In Eq. (4) this occurs at the turning point for which the oscillation amplitude would become negative. Hence, the maximum value of n , or n_{\max} , is the largest integer which satisfies the equation

$$n < \frac{1}{2\beta} (1 - \beta). \tag{5}$$

Using n_{\max} we can write the final position of the block (i.e., where it will come to rest) as,

$$\frac{x_{\text{final}}}{x_o} = (-1)^{n_{\max}} [2\beta(n_{\max} + 1) - 1]. \tag{6}$$

Equations (4) through (6) show that the quantities β and ω are the characteristic parameters which completely determine the motion of the system. The parameter ω sets the time scale of the oscillation, while the parameter β determines the number of oscillations and final position of the block. Substituting all possible values of β into Eq. (5) we find that there are four significant regions of interest.

First consider the case $\beta = 0$, or frictionless oscillation. Figure 2-(a) shows the first seven oscillations³ of this case. As expected for an undamped oscillation, and confirmed by Eq. (4) with $\beta = 0$, the oscillations have constant amplitude and are centered at the origin. In the limit that $\beta \rightarrow 0$, Eq. (5) shows that the oscillations repeat indefinitely as $n_{\max} \rightarrow \infty$.

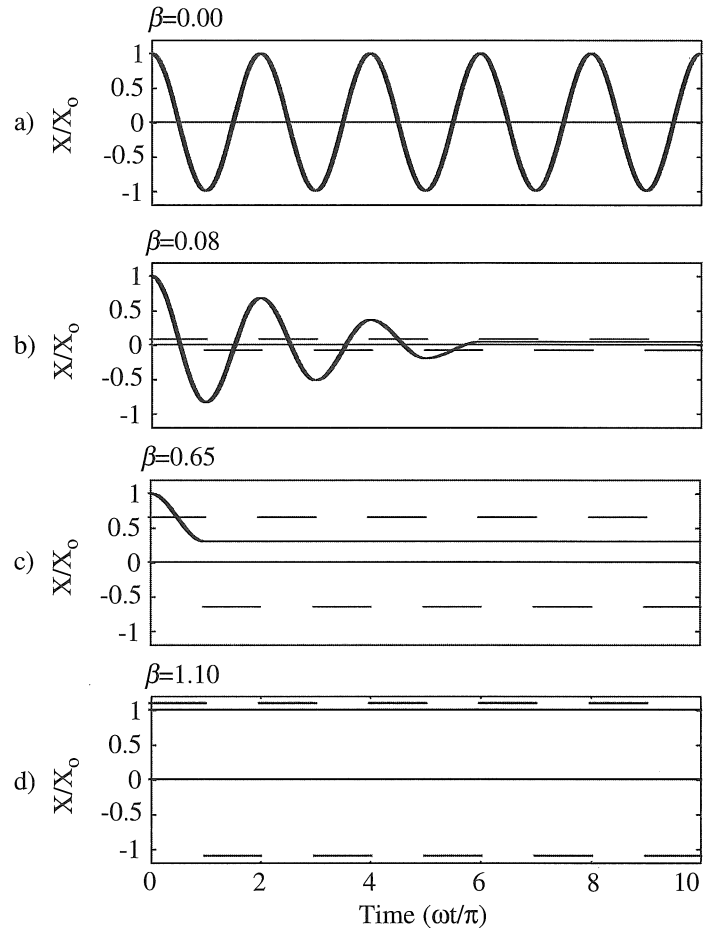


Figure 2. Displacement of block as a function of time in each of the four damping regimes. Horizontal lines show center of oscillation. (a) Undamped: $\beta=0.00$. (b) Under damped: $\beta=0.08$. (c) Critically damped: $\beta=0.65$. (d) Over damped: $\beta=1.10$.

The second region of interest corresponds to non-zero frictional forces that are much smaller than the initial spring restoring force. This is the region associated with $0 < \beta < \frac{1}{3}$. In this region the block oscillates over a finite number of periods before coming to rest. Figure 2-(b) shows the oscillation of a block with a relative frictional force of $\beta = 0.08$. For this frictional force, Eq. (5) gives $n_{\max} = 5$, which accounts for the observed six half cycles ($n=0$ to 5) before the block comes to rest. Equation (6) gives the final position of the block as $x_{\text{final}} = 0.04x_o$, which is slightly above the axis as shown in the figure.

When $\frac{1}{3} \leq \beta < 1$, Eq. (5) gives $n_{\max} = 0$. In this region the block comes to rest after one-half period. Using Eq. (6) we see that when $\beta = \frac{1}{3}$, the block comes to rest at the lowest point below the axis, or $x_{\text{final}} = -\frac{1}{3}x_o$. When $\beta = \frac{1}{2}$ the block comes to rest at the origin. For larger values of β the block comes to rest at points closer to its starting point. As an example of this, Fig. 2-(c) shows the case for $\beta = 0.65$, with $x_{\text{final}} = 0.30x_o$.

²Requiring zero initial velocity simplifies the mathematics of our problem, but does not change the physical results. To account for a non-zero initial velocity, Eq. (3) can be used to determine the block motion up to the first turning point. From the first turning point on, our derivation describes the block motion.

³The trajectories shown were obtained by two methods: numerical solution of Eq. (1), and from the analytical solution given by Eq. (4).

Finally, when $\beta \geq 1$, $n_{\max} = -1$, such that not even a half-oscillation is possible. In this case, the static frictional force is greater than the spring's restoring force and the block remains at its initial position. Fig. 2-(d) shows the case for $\beta = 1.10$. Since $n_{\max} = -1$, Eq. (6) gives the final position as $x_{\text{final}} = x_0$.

Energy Consideration

Consideration of the block's mechanical energy as a function of time provides additional insights into the physics of the system. When the spring is initially stretched by a distance x_0 , potential energy is introduced to the system. This gives the system an initial mechanical energy

$$E(0) = \frac{1}{2} kx_0^2. \tag{7}$$

Since the frictional force is a non-conservative force, it turns mechanical energy into heat. The amount of converted energy is obtained by integrating the frictional force over the distance the block has traveled,

$$\Delta E(t) = -\mu mg \int_s ds = -\mu mg \int_0^t |\dot{x}(t')| dt'. \tag{8}$$

The mechanical energy at any given time will be the sum of the spring's potential energy and the block's kinetic energy. It will also be equal to the initial mechanical energy less the energy dissipated, or

$$\frac{1}{2} kx^2(t) + \frac{1}{2} m\dot{x}^2(t) = \frac{1}{2} kx_0^2 - \mu mg \int_0^t |\dot{x}(t')| dt'. \tag{9}$$

Note that differentiating Eq. (9) with respect to time yields the equation of motion, Eq. (1). An interesting way to observe the energy evolution of an oscillating block is to examine its phase-space trajectory. If we define the horizontal axis of our phase space as the position of the block x , and the vertical axis as the ratio of the velocity to angular frequency, $\dot{x}\sqrt{\frac{m}{k}}$, Eq. (9) shows that in a frictionless case the trajectory would be a circle with radius proportional to the square root of the mechanical energy. When friction is included the trajectory becomes an inward spiral. The radius of that spiral is proportional to the square root of the mechanical energy at any given time.

Figure 3 shows the phase space plot for the oscillation of Fig. 2-(b). In this figure, when the radial vector is measured from the origin, the energy is continually decreasing. However, the figure can also be divided into two regions. The region given by the curves below the x-axis (P1-P2, P3-P4, and P5-P6) form arcs of concentric circles centered about point A, where $(X_A, Y_A) = (\beta, 0)$. The region given by the curves above the x-axis (P2-P3, P4-P5, and P6-P7) form arcs of concentric circles centered at point B, where $(X_B, Y_B) = (-\beta, 0)$. Points A and B correspond to the centers of oscillation shown in Fig. 2-(b). Matching the energy at the boundaries gives the correct time dependence of the mechanical energy. In this picture the block comes to rest when the block's position at a turning point (on the x-axis) falls for the first time between points A and B. The remaining energy stored in the static system at this point is evident.

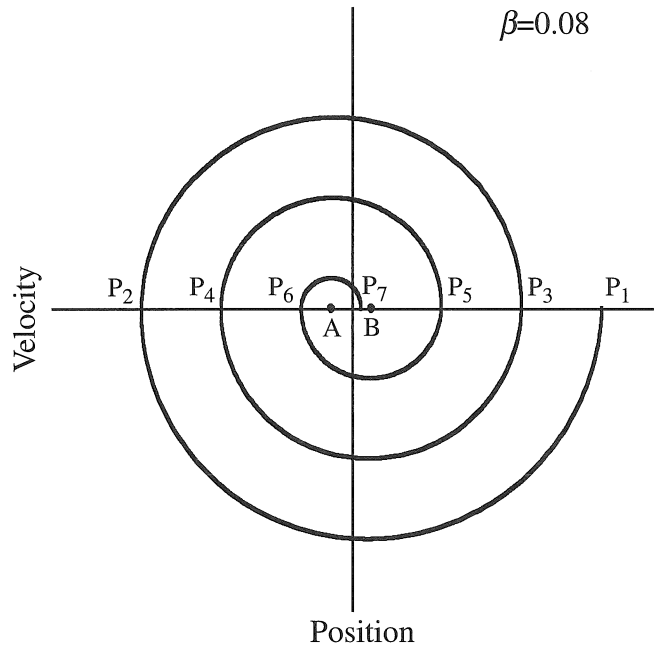


Figure 3. Phase space trajectory of an under damped block ($\beta=0.08$). The block starts at point P1 and spirals inward until coming to rest at point P7. The arcs P1-P2, P3-P4, and P5-P6 of the trajectory are semi-circles centered around point A. The arcs P2-P3, P4-P5, P6-P7 are semi-circles centered around point B.

Conclusions

We have analyzed the nonlinear dynamics of a harmonic oscillator damped by sliding (or kinetic) friction and have obtained an exact solution. The dynamics of this system differ considerably from a harmonic oscillator with linear viscous damping. For instance, in the case of the sliding friction, the envelope of the oscillation decays linearly [through the term proportional to $(2n+1)$ in Eq. (4)] and not exponentially as is the case with linear viscous damping. The local oscillation period is independent of the damping for the system with sliding friction, but not for the system with viscous damping. Only in the system with contact friction does the final state of equilibrium retain some stored energy. The motion of the mass subject to kinetic friction is characterized by an acceleration that changes discontinuously at the turning points (where the frictional force abruptly changes direction), whereas all the kinematic variables vary continuously in the case with viscous damping.

The relative magnitudes of the oscillation restoring force (kx_0) and the damping force (μmg) provide a means by which we can classify the motion in three distinct regimes: over damped, critically damped, and under damped. It can be seen from Eq. (2) that if the static frictional force is greater than the restoring force, there can be no motion. This is the case of over damping [See Fig. 2-(d)]. From Eq. (5), one can see that for a static frictional force $\frac{1}{3} < \beta < 1$, there is motion but not a complete oscillation. The block completes only half an oscillation [See Fig. 2-(c)] and can be classified as a critically damped oscillator. For $\beta < \frac{1}{3}$, the block completes at least one full oscillation before coming to rest

[See Fig. 2-(b)], and can be classified as an under-damped oscillator. Finally, when $\beta = 0$, the block oscillates indefinitely, which is an undamped oscillator.

It will be interesting to study resonance phenomena in the present system. The system presented here may also be useful in experimentally studying sliding friction.

References

- [1] C. Baratt and G. L. Strobel. American Journal of Physics **49** (5), 500, (1981).
- [2] I. R. Lapidus. American Journal of Physics **52** (11), 1015, (1984).
- [3] I. R. Lapidus. American Journal of Physics **38** (11), 1360, (1970).

Construction and Evaluation of A Semi-Portable Radiotelemetry Tower System At Prairie Fork Conservation Area, Missouri

Robert K. Woeck, Joshua J. Millspaugh, and Tony W. Mong
Department of Fisheries and Wildlife Sciences, University of Missouri
302 Anheuser-Busch Natural Resources Building, Columbia, MO 65211

Abstract: Triangulation techniques are often used to estimate the location of radio-marked animals, but many hand-held and mobile antennae systems have relatively low accuracy. Use of fixed-station radiotelemetry towers can increase location range and accuracy, yet the inability to move towers ultimately limits their effectiveness in the field. We designed and tested a unique semi-portable telemetry tower system at Prairie Fork Conservation Area in mid-Missouri during the fall and winter of 2000 and 2001. Each tower mast telescopes to a height of 9.1 meters, rotates 360 degrees, and can be easily moved by two people between permanent concrete base sites with complete set up taking approximately 20 to 30 minutes. Construction materials for each tower, not including antennae and cables, was \$248 with the base materials adding an additional \$18. After construction, we assessed error of the tower system and a three-element hand held Yagi antennae for comparison. Accuracy was assessed by placing 8 beacon transmitters of two different sizes (turtle and deer) at known coordinates throughout the study site. We compared known azimuths to the estimated azimuths to assess accuracy. Mean error for the tower system ($e = 2.5^\circ$, $SD = 2.0$, $n = 122$) was significantly lower ($P < 0.001$) than for the hand-held antenna ($e = 10.9^\circ$, $SD = 6.6$, $n = 121$); no difference in mean error was noted between deer and turtle transmitters ($P = 0.623$). The convenience, efficiency, and accuracy of the tower system provides a unique option for radiotelemetry data collection while reducing costs by limiting the amount of equipment needed to adequately cover a study area with a traditional tower system.

Key words: Missouri, portable mast, radiotelemetry, radio tracking, telemetry, telemetry error, tower, tower construction, transmitter

Introduction

Radiotelemetry is commonly used to assess space use patterns and survival of wild vertebrates (Millspaugh and Marzluff 2001a). In fact, roughly one-third of all papers published in *The Journal of Wildlife Management* over the past 20 years were telemetry-based (Millspaugh and Marzluff 2001b). Triangulation and homing (i.e., direct observation) are two common techniques for estimating the location of radio-collared ani-

mals. Direct observation of radio-collared animals is generally considered a more accurate method of determining animal locations but may influence animal behavior (Kernohan et al. 2001). Furthermore, many free-ranging animals are relatively inaccessible, secretive, and sensitive to human influence, and thus are not good candidates for homing. Triangulation on the other hand is often more practical and efficient when monitoring large numbers of animals and animals that range over great distances.

Triangulation involves recording two or more azimuths from known locations to the radio-transmitter on the animal (White and Garrott 1990). Using azimuths recorded from known locations and trigonometric relationships, the location of a radio-tagged animal may be estimated with an associated measure of error (Heezen and Tester 1967, Lenth 1981). Azimuths may be obtained from either large, fixed receiving stations (i.e., towers) or smaller, mobile devices (e.g., hand-held antennas, vehicle mounted antennas). Often, azimuths obtained from towers are more accurate (Slade et al. 1965, Anderson and DeMoor 1971, Merson et al. 1982), varying by as little as ± 2 degrees. Use of fixed-station radiotelemetry towers can also increase location range, yet the inability to move towers ultimately limits their effectiveness in the field.

The goal of this study was to design and construct a semi-portable telemetry tower system at Prairie Fork Conservation Area (PFCA) that was easy to set up and maintained a high level of accuracy. After construction in the fall/winter of 2000, we tested the accuracy of the system in the fall/winter of 2001 and compared tower accuracy with a hand-held 3-element Yagi antenna.

Study Area

PFCA is a publicly owned tract of land of approximately 288 hectares located in Callaway County, Missouri, Township 48, Range 7 West. The site lies within the oak-hickory forest/prairie transition zone at the southern border of what was once the Grand Prairie, now the largely agricultural northern half of Missouri. Approximately 70% of the site is open, previously tilled prairie. Over 350,000 people live within an 80-km radius of PFCA, with the major metropolitan area of St. Louis being less than 130 km away. Agriculture is the primary land use within a 40-km radius of PFCA, with an increase recently in the breakup of larger farms into smaller acreages owned by absentee landowners.

The topography of PFCA is gentle, with a total elevational gradient of approximately 37 m; no steeply incised banks or cliffs are present. There is one permanent stream running through the property with several intermittent streams throughout the site. Twenty small ponds are scattered over the area, most of them having been created to hold water for livestock use.

Tower & Base Placement and Design

Tower base placement was determined using a modification of White's (1985) recommendations for a square, flat study site and by taking into account topographical variation and interference from power lines. First, White's (1985) ideal geometric tower placement was overlaid on a map of PFCA. Next, site coordinates were moved to the nearest high point away from power-lines (White and Garrott 1990), resulting in a configuration with the best possible use of the site topography and geometric design.

A semi-portable tower design was created by modifying the towers and materials reported by Banks et al. (1975), Medina and Smith (1986), and Merson et al. (1982) (Figure 1). Each tower was constructed using a stacked, horizontally-oriented RA-4A 5-element Yagi array (Telonics, Inc., Mesa, AZ, USA) attached to a 9.1 m telescoping mast (Channel Master, Smithville, NC, Model #1830) (Figure 1). A compass rosette attached to the tower base and a pointer attached to the telescoping mast were used to estimate direction to the nearest degree (Figure 2). Dual coaxial RW-5 cables were routed inside the hollow mast to a TAC-5 null precision combiner box (Telonics, Inc., Mesa, AZ, USA). Tower masts were guyed with nylon rope (Figure 1); to prevent interference, no steel cables were used. Also, no guys were attached to the mast within 3 meters of the antenna array. Eight guy wires were affixed to the mast; 4 were attached to the mast at 3 meters and 4 at 6 meters (Figure 1). Guy wires were anchored to four steel posts buried horizontally $\frac{1}{2}$ meter deep and 4.3 meters from the base center in the four cardinal directions. A length of steel rope that exited the ground was attached to each post to allow for the connection of the tower guy wires. This design has withstood wind speeds up to 80 km/hr. With 2 people, complete tower setup at a pre-constructed base site takes approximately 20-30 minutes. The towers rotate 360 degrees and are easily moved by two people between permanent concrete bases.

Sixteen concrete bases, 0.6 m x 0.6 m x 10 cm, were established throughout PFCA (Figure 2). Each base was reinforced with steel rebar, and all bases were given at least two days to set before use. Three lengths of 0.9525 cm all-thread rod were set vertically into each base with 10.5 cm exposed above the concrete. This exposed rod was then used to attach a two-piece steel thrust bearing (J & L Technologies, Columbia, MO, USA) and a two-piece wooden compass rosette (Figure 2). Complete construction of one base, including the buried steel posts, took approximately 2 hours. The base stations were established low to the ground, permitting mowing and prescribed burning with no negative effects on the bases. Coordinates of the base stations were determined with a global positioning system (GPS) unit corrected with Differential Code GPS (DGPS) to an accuracy of ± 1 meter. A pre-drilled wooden block was placed over the

exposed rod at each unused base to protect the rods from damage that might occur from tires or feet unexpectedly finding the base. Construction materials for each tower, not including antennae and cables, was \$248 with the base materials adding an additional \$18 (Table 1).

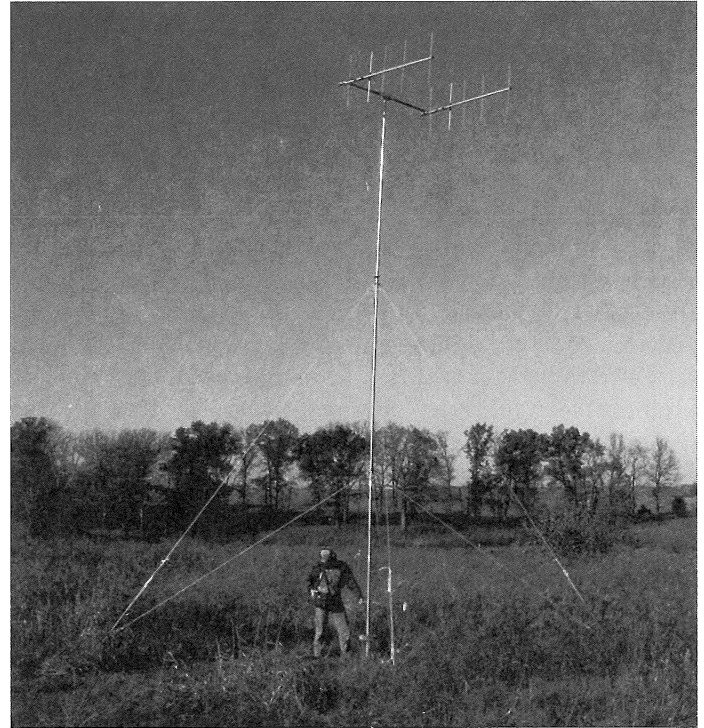


Figure 1. Fully assembled semi-portable radiotelemetry tower at Prairie Fork Conservation, Missouri.



Figure 2. Compass rosette and steel thrust bearing connected to concrete base via 0.9525 cm all-thread rod.

Table 1. Materials and cost for tower and base construction of a semi-portable radiotelemetry tower built at Prarie Fork Consevation Area, Missouri.

Materials	Cost
RA-NX-5 Precision Direction Finding Antenna Arrays (Telonics, Inc., Mesa, AZ, USA)	\$406 each
9.1 meter telescoping mast model #1830 (Channel Master, Smithville, NC, USA)	\$50 each
Rotating steel thrust bearings (J&L Technologies, Columbia, MO, USA)	\$170 each
Null combiner box (Telonics, Inc., Mesa, AZ, USA)	\$285 each
Cable and adapters, 1 tower (Telonics, Inc., Mesa, AZ, USA)	\$131 each
27.2 kg sacks of concrete, 2 per base	\$6.00 each
Various bolts, nuts, washers, wood, nylon, rope, steel cable, steel posts, etc.	\$40 each
Total Material Costs per tower	\$1,070 each
Total Material Costs per base	\$18 each
Total Cost One Working Tower System	\$1,088 each

Error Assessment

Bearing accuracy was evaluated for the tower system in fall 2001; a hand-held antenna error assessment was conducted concurrently for comparison. Data were collected from all 16 permanent receiving stations. A folding 3-element hand-held Yagi (AF Antronics, Inc., Urbana, IL, USA) held 1.8 meters high was used during the hand-held assessment. Only the null signal (Banks et al. 1975) was used to determine directionality for the towers while the loudest signal method (Springer 1979) was used with the hand-held antenna. ATS (Advanced Telemetry Systems, Isanti, Minnesota) radio receivers (Model #R2000) with headphones were used by the three field personnel.

Transmitter test locations were determined by placing a 400m x 400m grid over the study site (White and Garrott 1990) to include diverse topographic and vegetation conditions. Transmitters were attached to wooden stakes at heights of 0.66 meters for deer-size transmitters and 0.33 meters for turtle-size transmitters. Four deer (Lotek Engineering Inc., Newmarket, Ontario, Canada) and four turtle (Advanced Telemetry Systems, Isanti, Minnesota) transmitters (164-165 MHz) were placed at the nearest 4 (x = 0.703 km, Range = 0.2 – 1.7 km, SE = 0.047 km) of 18 grid locations to the base location being tested for bearing accuracy. Azimuths were randomly taken from the receiving station being evaluated to each of the 4 beacon locations to avoid observer bias (Lee et al. 1985); the sequence was repeated five times for each of the 8 transmitters. A second observer recorded

azimuths so a previous reading would not influence the investigator. Thus, there were five bearing estimates for each of the eight transmitters from each of the 16 tower locations.

Analytical Methods

Deviate observations resulting from signal bounce and other factors may significantly affect error assessments (Garrott et al. 1986). Without the use of a technique that is relatively insensitive to gross outliers (Lenth 1981), these aberrant bearings must be identified and removed from bias and precision calculations (Lee et al. 1985). Consequently, prior to data analysis, we identified outliers from the data set based on frequency distributions. To estimate azimuth accuracy, we used the replicated measurements of error from each base station to calculate a mean error (\bar{e}), and a standard deviation (SD). Error (e) was defined as the difference between the true azimuth (θ), determined using a hand held GPS unit, and the estimated azimuth ($\hat{\theta}$) of the transmitter for each azimuth i and replicate j as:

$$e_{ij} = \theta_i - \hat{\theta}_{ij} \quad (1)$$

Mean error, an estimate of bias, was obtained by summing all errors for all stations including replicates from individual stations, and then dividing this number by the product of the number of locations and the number of replicates (Lee et al. 1985) as

$$\bar{e} = \frac{\sum_{i=1}^n \sum_{j=1}^r e_{ij}}{nr} \quad (2)$$

where n is the number of reference transmitter locations and r is the number of azimuth replicates. Finally, for a measure of the repeatability or amount of variation of estimated bearings, we estimated standard deviation as (Lee et al. 1985, White and Garrott 1990):

$$SD = \left[\frac{\sum_{i=1}^n \sum_{j=1}^r (e_{ij} - \bar{e})^2}{(nr-1)} \right]^{1/2} \quad (3)$$

To determine if there was a difference in the mean error between the tower and hand-held antenna we used one-way ANOVA (Zar 1996). We tested for differences in mean error and precision using transmitter type (deer or turtle), observers, and wind speed as factors in a one-way ANOVA model. Last, we used a backward selection procedure in a generalized linear model (McCullagh and Nelder 1989) to determine which of these factors were most correlated with mean error. All analyses were considered significant at $P < 0.05$.

Results

Based on a frequency distribution of tower error estimates, we noted that most tower azimuths (94.1%) were within 0 and 10 degrees of the true azimuth (Figure 3). Consequently, for our tower assessment, we defined absolute errors of ≥ 10 degrees as signal bounce and eliminated them from further consideration (Slade et al. 1965, Lee et al. 1985, Zimmerman and Powell 1995). There was no clear cut off point for handheld outliers, however, and to facilitate a valid comparison, we eliminated the same percentage (5.9%) of outliers from the handheld data set (Figure 4).

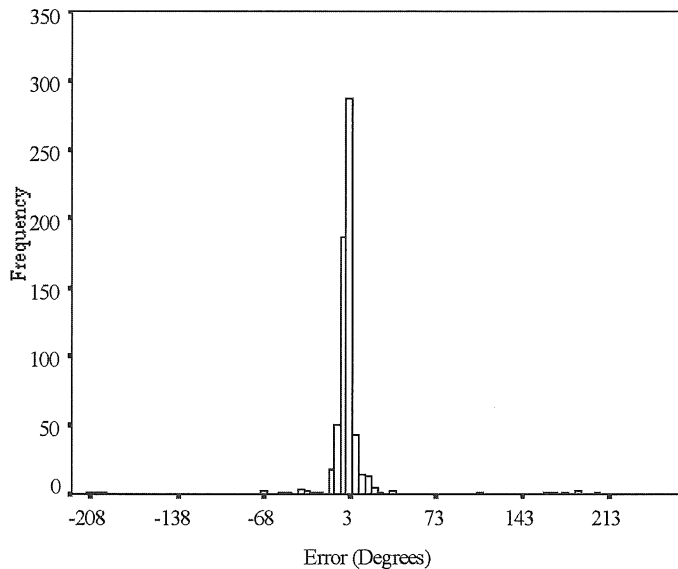


Figure 3. Frequency of azimuth errors for tower system at Prairie Fork Conservation Area. We considered errors ≥ 10 degrees as aberrant (5.9%) and removed them from the data set.

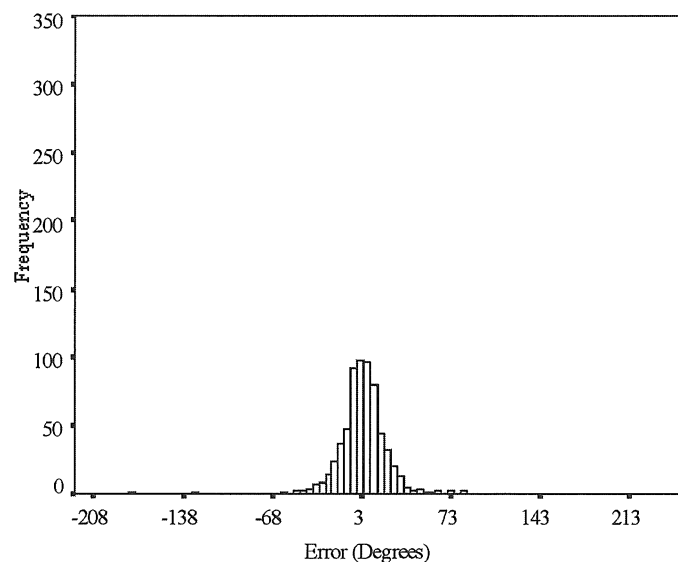


Figure 4. Frequency of azimuth errors for hand-held antenna error assessment at Prairie Fork Conservation Area. We removed 5.9% of gross outliers, equal to that removed from the tower data, for the comparison.

Mean error for the tower system ($e = 2.5^\circ$, $SD = 2.0$, $n = 122$) was significantly lower ($P = 0.0001$) than for the hand-held antenna ($e = 10.8^\circ$, $SD = 6.6$, $n = 121$). We noted no difference in mean error between deer ($x = 7.35$, $SD = 8.49$, $n = 126$) and turtle transmitters ($x = 8.11$, $SD = 9.41$, $n = 128$) for the tower system ($P = 0.623$). Mild observer bias was noted for the tower ($x = 3.00$, $SD = 2.31$, $n = 48$ observer 1; $x = 2.52$, $SD = 2.36$, $n = 23$ observer 2; $x = 2.08$, $SD = 1.42$, $n = 51$ observer 3) ($P = 0.077$) but not hand-held ($x = 13.26$, $SD = 12.47$, $n = 48$ observer 1; $x = 11.88$, $SD = 10.01$, $n = 24$ observer 2; $x = 12.53$, $SD = 7.81$, $n = 56$ observer 3) ($P = 0.103$). We observed no effect of wind speed on error ($n = 47$, 0-8 km/hr; $n = 39$, 0-16 km/hr; $n = 23$, 8-24 km/hr; $n = 15$, 16-32 km/hr) ($x = 2.06$, $SD = 1.01$, $n = 122$); however, data were not collected when wind speeds exceeded 32 km/hr. Last, the backward selection procedure selected observer ($P = 0.023$) as the most influential factor in the generalized linear model; other factors were not significant.

Discussion

The semi-portable radiotelemetry tower system at PFCA was more accurate than traditional hand-held antennae for triangulation under the situations we evaluated. We believe the accuracy observed for the tower arrays at PFCA would adequately meet many research needs on similar sites. Hand-held systems will continue to be useful in studies where homing is necessary (e.g., behavioral studies) and feasible, and when strong winds preclude use of a tower system.

We offer the following suggestions to those interested in developing a semi-portable tower system. 1. All observers using towers should be trained to avoid observer bias. This should involve repeated practice and continued evaluation of their accuracy during the course of normal research activities. 2. In planning future tower sites, we recommend that areas under and near power lines and buildings be avoided because these structures cause signal bounce and difficulties in distinguishing a null signal. 3. Great care should be taken when collecting bearing estimates with the tower system when wind speeds exceed 16 km/hr, and no estimates should be recorded when winds exceed 24 km/hr as the null signal can be difficult if not impossible to distinguish.

The convenience, efficiency, and accuracy of the tower system provides future investigators with a unique way to collect telemetry data. The ability to move towers easily allows the best use of a limited number of antennas, enables investigators a greater choice of tower locations, and reduces costs by limiting the amount of equipment needed to adequately cover a study area.

Acknowledgments

We thank all of those individuals who helped with the construction and implementation of the tower design and assessment; C. Rittenhouse, J. Sumners, B. Washburn, and B. Woeck. Funding for this study was provided by the Prairie Fork Conservation Fund administered by the Missouri Department of Conservation and The School of Natural Resources, University of Missouri.

Literature Cited

- Anderson, F. and P. P. DeMoor. 1971. A system for radio tracking monkeys in dense bush and forest. *Journal of Wildlife Management* 35:636-643.
- Banks, E. M., R. J. Brooks, and J. Schnell. 1975. A radiotracking study of home range and activity of the brown lemming (*Lemmus trimucronatus*). *Journal of Mammalogy* 56:888-901.
- Garrott, R.A., G.C. White, R.M. Bartmann, and D.L. Weybright. 1986. Reflected signal bias in biotelemetry triangulation systems. *Journal of Wildlife Management* 50:747-752.
- Heezen, K. L. and J. R. Tester. 1967. Evaluation of radio-tracking by triangulation with special reference to deer movements. *Journal of Wildlife Management* 31:124-141
- Kernohan, B. J., R. A. Gitzen, and J. J. Millspaugh. 2001. Analysis of animal space use and movements. Pages 125-166 in J. J. Millspaugh and J. M. Marzluff, editors. *Radio Tracking and Animal Populations*. Academic Press, San Diego, California, USA. 467 pages.
- Lee, J. E., G. C. White, R. A. Garrott, R. M. Bartmann, and A.W. Aldrege. 1985. Assessing accuracy of a radiotelemetry system for estimating animal locations. *Journal of Wildlife Management* 49:658-663.
- Lenth, R. V. 1981. On finding the source of a signal. *Technometrics* 23:149-154.
- McCullagh, P., and J. A. Nelder. 1989. *Generalized linear models*. Second edition. Monographs on statistics and applied probability No. 37. Chapman & Hall, London, England.
- Medina, A. L. and H. D. Smith. 1986. Designs for an antenna boom and masts for telemetry applications. *Wildlife Society Bulletin* 14:291-297.
- Merson, M. H., R. E. Byers, and L. D. Leta. 1982. A portable antenna base for fixed-station radiotracking. *Wildlife Society Bulletin* 10:44-45.
- Millspaugh, J. J., and J. M. Marzluff, editors. 2001a. *Radio Tracking and Animal Populations*. Academic Press, San Diego, California, USA. 467 pages.
- Millspaugh, J. J., and J. M. Marzluff. 2001b. Past trends and future needs. Pages 383-396 in J. J. Millspaugh and J. M. Marzluff, editors. *Radio Tracking and Animal Populations*. Academic Press, San Diego, California, USA. 467 pages.
- Slade, N. A., J. J. Cebula, and R. J. Robel. 1965. Accuracy and reliability of biotelemetric instruments used in animal movement studies in Prairie grasslands of Kansas. *Transactions of the Kansas Academy of Science* 68:173-179.
- Springer, J. T. 1979. Some sources of bias and sampling error in radio triangulation. *Journal of Wildlife Management* 43:926-935.
- White, G. C. and R. A. Garrott. 1990. *Analysis of wildlife radio-tracking data*. Academic Press, San Diego, California. 383 pages.
- White, G. C. 1985. Optimal locations of towers for triangulation studies using biotelemetry. *Journal of Wildlife Management* 49:190-196.
- Zar, J. H. 1996. *Biostatistical analysis*. Third edition. Prentice-Hall, Englewood Cliffs, New Jersey, USA.
- Zimmerman, J. W. and R. A. Powell. 1995. Radiotelemetry error: location error method compared with error polygons and confidence ellipses. *Canadian Journal of Zoology* 73: 1123-1133.

Elemental Distributions in Eutric Brunisols From The Northern Glacial Lake Agassiz Region Of Manitoba

Michael T. Aide* and Gary J. Cwick.

Department of Geosciences, Southeast Missouri State University, 1 University Plaza, Cape Girardeau, MO 63701.

* corresponding author

Abstract: The glacial Lake Agassiz region of central Manitoba is an extensive plain composed of fine-grained lacustrine sediments, interspersed with organic soils and fens. The shallow soils are generally developed in varved sediments and show limited soil profile development. The objectives of this research were: (1) to determine the major soil profile characteristics, (2) to isolate the soil processes responsible for soil expression, and (3) provide a geochemical baseline assessment of selected elements. The geochemical baseline assessment involves an inventory of metal concentrations to be used to determine the impact of anticipated mining activities in this region. Calcium and Mg, as a result of soil acidification, were the only elements showing any depletion in the upper inorganic horizons. Other soil forming processes recognized as important to soil development include: soil structure formation, development of a small amount of Fe-oxides, and the buildup of organic materials. The clay mineralogy is considered to be largely inherited.

Key Words: Transition metal mobility, rare earth elements, Brunisols, boreal soils.

Introduction

Fine-textured glacial Lake Agassiz sediments broadly characterize soil landscapes between the Churchill and Nelson Rivers in the northern boreal forests of Manitoba. Relatively little geochemical information is known about these sediments or soils. Equally important, the soils of this region have not been mapped with the detail commonly witnessed in agriculturally-oriented or populated regions of North America. Thus, only the most rudimentary soil genesis and best land use interpretations are available. In the area selected for this inquiry, the majority of the soils have been classified according to the Canadian system as belonging to the Brunisolic order.

Brunisols are generally characterized as having sufficient soil profile development to exclude them from the Regosolic Order (roughly equivalent to Entisols), but they lack the degree of development specified for soils of other orders. To a first approximation, Brunisols are similar to Inceptisols within the U.S. soil classification scheme. The Brunisolic order is subdivided into four Great Groups: Melanic Brunisols, Eutric Brunisols, Sombric Brunisols and Dystric Brunisols.

The soils of the study area are largely Eutric Brunisol's, frequently exhibiting a Bm horizon. The Bm horizon may have any or all of the following characteristics: stronger chroma or redder hue than the underlying material, partial or complete removal of carbonates, slight illuviation of clay based mainly on the presence of an Ae horizon (E horizon in U.S.), and a change in the soil structure from that of the original material (Agriculture Canada Expert Committee on Soil Survey, 1987). Eutric Brunisols have a relatively high base saturation as indicated by their pH and lack of a well-developed mineral-organic surface horizon. Many of the soils in the study area are Orthic Eutric Brunisols, having an organic surface horizon overlying a brownish-colored, base-saturated Bm horizon. Eluviated Eutric Brunisols are also common in the study area, having an Ae (eluvial horizon) overlying a Bm horizon (Agriculture Canada Expert Committee on Soil Survey, 1987).

Previous geochemical investigations (McKeague and Wolynetz 1980; Mermut et al., 1996) involved a range of lithologies and multiple soil orders, providing an important overview of the region but lacking the detail for assessing the impact of mining in a localized region. Thompson, Manitoba, has become a mining area with massive nickel deposits located at the juncture of two sutured plates of the Canadian Precambrian Shield.

The objectives of this research were: (1) to determine the dominant soil profile characteristics, (2) to assess which soil forming processes are most active, and (3) to provide a geochemical assessment of selected elements. The last of these objectives is important because mining activities in the study area are anticipated and a geochemical baseline would be important to assess the long-term impact that mining may have on the soils of this region. In addition to mining, tourism has become an important commercial activity.

Materials and Methods

Study Area

The study area is located in a region that extends about 45 km west of Thompson, Manitoba (Fig. 1). Situated within the Canadian Shield physiographic region, the landscape ranges from flat to broadly rolling. Granitized gneisses and schists, along with metasedimentary and mafic volcanics, are the major

lithologies (Klassen, 1983, 1986; Kaszycki, 1989). The topography reflects the glacially smoothed underlying bedrock surface, which has been minimally modified by glacial drift. Numerous small lakes and wetlands, frequently connected by low gradient minor streams, transverse the study area.

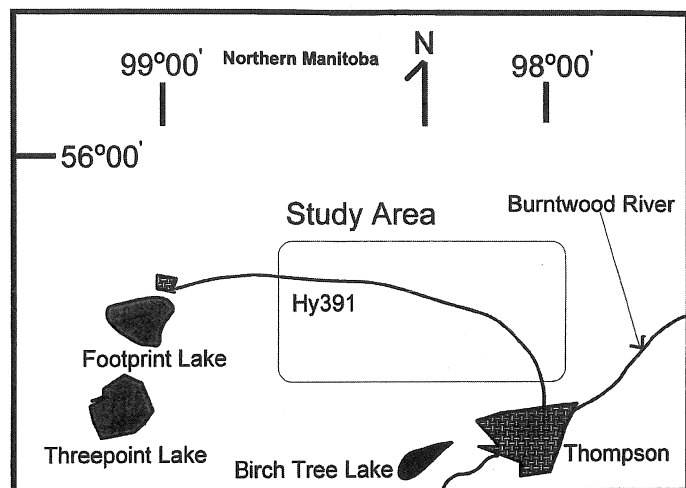


Fig. 1. Map of the study area.

The climate is cold, lying within the discontinuous permafrost belt, restricting the majority of the soil weathering processes to the warmest months of summer and early fall. Larsen (1980) reported that the mean annual temperature is -4°C . The boreal vegetation is relatively uniform and sampling sites may be chosen expressly to minimize vegetation differences. Reconnaissance surveys by the authors suggest that the vast majority of the sediments are varved, consisting of alternating thin lamella (1 to 10 mm) distinguished by color. The varved lacustrine sediments suggest that the bulk chemical composition of the upper 2 meters is somewhat similar among sites; however, individual varves may show distinct mineralogical and compositional differences.

Klassen (1983) reported that the upper gray clay was derived from shaley and calcareous till located to the south and southwest and the lower brown clays were derived from brown tills located to the east. Aide and Cwick 1998 investigated the clay mineralogy of these varved sediments and reported that vermiculite, hydrous mica (clay mica), and kaolinite were the dominant clay minerals and chlorite and smectite showed secondary occurrences. The vermiculite was shown to be partially hydroxyl-Al interlayered.

The Eutric Brunisols are generally developed in fine-textured and slowly permeable lacustrine sediment. The majority of the soils maintain a udic soil moisture regime, with some depressional soils or soils adjacent to fens having an aquic moisture regime. Redoximorphic features such as concretions (nodules) and mottling patterns were not evident in these soils. Aide and Cwick (1998), using Brunisol soils from this study area, showed that the free Fe-oxide content ranged from 10 to 20% of the total Fe content, inferring a very limited degree of soil weathering. The Bm horizons are largely distinguished from the underlying parent material by development of fine and medium, strong, sub-

angular block structures and the Ae horizons, where present, were distinguished by fine and medium, moderate platy structures. Fig. 2 illustrates the dominant soil profile features and their landscape positions.

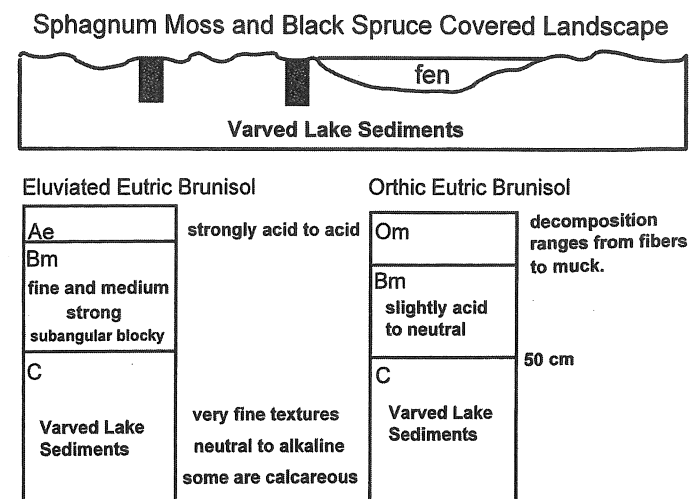


Fig. 2. Illustration of the soils and landscape.

The forest vegetation generally consists of black spruce (*Picea mariana* (Miller) BSP) with minor inclusions of tamarack (*Larix laricina* (DuRoi) K. Koch). The herbaceous layer is mostly composed of sphagnum moss (*Sphagnum* spp.) with minor expressions of bunch berry (*Cornus canadensis* L.), cranberry (*Vaccinium* spp.), dewberry (*Rubus* spp.), fireweed (*Epilobium augustifolium* L.), labrador tea (*Ledum groenlandicum* (Oeder)), reindeer moss (*Cladina* spp.), rose (*Rosa* spp.), and spikemoss (*Lycopodium complanatum* L.).

Soils selected for inquiry include six inorganic soil sites classified as Eutric Brunisols (Cryumbrepts). Three of the sites were classified as Orthic Eutric Brunisols and the remaining three sites were classified as Eluviated Eutric Brunisols. In addition, auger-sampling involving 23 additional sites were performed to supply sufficient sampling material for the geochemical assessment. The 23 selected sites were roughly evenly divided between the orthic and eluviated Brunisolic suborders.

Site and Laboratory Analysis

Soils were described and sampled from pits using standard methods (Agriculture Canada Expert Committee on Soil Survey, 1987). Bulk density was estimated using the core method, with triplicate measurements for each soil horizon (Carter, 1993). Bulk samples were obtained from multiple points in each soil horizon and bulk blended to promote sample representation. Samples taken for routine physical and chemical analysis were air-dried and sieved to remove fragments greater than 2 mm. Samples for chemical analysis were oven-dried (110°C), whereas air-dried samples, with known moisture contents, were used for estimating the particle size distribution. The particle size distribution was estimated by centrifuge fractionation and wet sieving after Na saturation, H_2O_2 removal of soil organic matter and dithionite-citrate-bicarbonate extraction of the Fe-oxide fraction

(Carter, 1993). Routine soil characterization methods included: pH in 0.01 M CaCl₂, the 1 M ammonium acetate extraction of extractable bases (pH 7), 1 M KCl titratable acidity, soil organic carbon by the Walkley-Black method and total N by micro-Kjeldahl (Carter, 1993). The soil organic matter content (SOM) was estimated using thermal induction at 475°C for 24 hours. In addition, soil material from histic epipedons were ashed by thermal induction at 475°C, followed by uptake in 5% nitric acid and analyzed for Na, K, Ca, Mg, P, Fe, Mn, Cu, Zn, B, and other selected transition metals by inductively-coupled plasma-emission spectroscopy (ICP).

Elemental analysis of soil horizons was determined by instrumental neutron activation analysis (INAA) [Ba, Ce, Cr, Cs, Eu, Fe, La, Lu, Na, Nd, Rb, Sm, Tb, Th, U, Yb] and also by inductively-coupled plasma-emission spectroscopy (ICP) [Ag, Al, B, Ca, Co, Cu, K, Mg, Mn, Ni, P, Pb, S, Sc, Sr, Ti, V, Y, Zn and Zr] after aqua-regia (AR) digestion. The AR digestion method involves heating the sample in aqua-regia at 80°C for 1 hour, followed by filtration and ICP analysis. This extraction completely recovers elements associated with the exchangeable, organic and sesquioxide fractions and, to a limited extent, the phyllosilicate fraction. Quartz, orthoclase and albite, anatase, rutile and other selected minerals are largely unaffected by the AR extraction. The INAA and AR procedures were performed by XRAL Laboratories (Toronto, Ontario). Statistical analysis involved

Corel QuatroPro for mean, standard deviation, linear regression and Pearson correlations.

Results and Discussion

Soil Characterization

The Eluviated Eutric Brunisol soils have an Ae - Bm - C horizon sequence, whereas the Orthic Eutric Brunisols have an O - Bm - C horizon sequence (Table 1). These moderately shallow soils are the dominant inorganic soils of the study area. The H horizon in site 1 consists of decomposed litter, whereas the histic epipedons range from relatively undecomposed (Of = Oi in U.S. Soil Taxonomy) and semi-decomposed fibers (Om = Oe in U.S. Soil Taxonomy) to nearly completely decomposed fibers (Oh = Oa in U.S. Soil Taxonomy). For the Orthic Eutric Brunisol pedons, the soil organic carbon contents of the Of horizons range from 19.8 and 29.4%, whereas the soil organic carbon contents of the Om and Oh horizons range from 41.7 and 40.8% (Table 2). The pH of the Ae and O horizons range from strongly acid to neutral, whereas the B and C horizons typically have a near-neutral pH (Table 1). Calcium is the dominant exchangeable cation, especially in the O horizons. The KCl titratable acidity is only important in the O and Ae horizons, corresponding with the more acidic soil pH (Table 1). Calcite (micrite) was indicated in some of the C horizons by a strong effervescence with 0.1 M HCl.

Table 1. Selected soil profile features and properties.

Horizon	Depth (cm)	pH CaCl ₂	—Fine Earth Fraction—			von Post	—Extractable cations—				KCl acidity
			Clay (%)	Silt (%)	Texture		Ca	Mg	K	Na	
—————(cmol _(p+) kg ⁻¹)—————											
Eluviated Eutric Brunisol (Site 1)											
H	0-5	5.8	53	35	clay		10.61	1.70	0.91	0.10	1.23
Ae	5-15	6.1	51	42	silty clay		6.93	1.08	0.69	0.13	0.62
Bm	15-61	6.1	57	39	clay		8.74	1.29	0.91	0.16	0.15
Eluviated Eutric Brunisol (Site 2)											
Ae	0-3	6.4	60	37	clay		6.47	1.49	0.75	0.12	1.16
Bm	3-10	7.2	32	61	silty clay loam		9.74	0.69	0.52	0.10	0.00
C	10-51	7.2	15	84	silt loam		9.77	0.29	0.28	0.10	0.00
Eluviated Eutric Brunisol (Site 3)											
Ae	0-18	4.9	44	51	silty clay		2.11	0.49	0.46	0.12	4.16
Bm	18-15	5.2	44	51	silty clay		4.38	0.94	0.62	0.12	0.22
Bm2	51-70	6.3	50	48	silty clay		7.48	1.72	0.84	0.17	0.13
Eluviated Eutric Brunisol (Site 4)											
Of	0-28	6.4	—	—		4	13.92	1.41	0.42	0.22	0.26
Of2	28-33	6.5	—	—		4	13.37	1.53	0.36	0.32	0.21
Bm	33-53	6.7	43	54	silty clay		6.97	1.10	0.35	0.17	0.14
Bm2	53-76	6.7	49	49	silty clay		6.87	1.03	0.36	0.17	0.14
Orthic Eutric Brunisol (Site 5)											
Oh	9-0	6.8	—	—		10	38.71	18.09	0.31	0.39	1.72
Bm1	0-18	6.5	40	55	silty clay		25.10	6.88	0.62	0.31	0.10
Bm2	18-38	6.6	56	19	clay		17.15	4.68	0.60	0.18	0.10
BC	38-56	6.8	56	16	clay		16.81	4.04	0.46	0.19	0.10
Orthic Eutric Brunisol (Site 6)											
Om	19-9	4.6	—	—		9	20.00	7.38	0.30	0.28	11.81
Oh	9-0	5.7	—	—		7	36.65	7.41	0.10	0.37	6.81
Bm	0-41	6.7	59	28	clay		16.84	5.77	0.61	0.25	0.21
C	41-56	6.7	37	34	clay loam		17.75	4.26	0.55	0.18	0.11

Table 2. Selected features and properties of surface horizons.

Horizon	Nitrogen Phosphorus Sulfur			Organic C	C/N	C/P	C/S	Bulk density g cm ⁻³
	percent							
Eluviated Eutric Brunisol (Site 1)								
H	0.59	0.06	0.05	14.6	24.7	243	292	1.5
Eluviated Eutric Brunisol (Site 2)								
Ae	0.24	0.04	0.04	6.4	26.8	161	161	1.5
Eluviated Eutric Brunisol (Site 4)								
Of	0.67	0.08	0.08	19.8	29.5	247	247	0.07
Of2	1.07	0.09	0.14	29.4	27.4	326	209	0.07
Orthic Eutric Brunisol (Site 5)								
Oh	0.69	0.06	0.08	27.3	39.5	455	341	0.2
Orthic Eutric Brunisol (Site 6)								
Om	1.64	0.1	0.24	41.7	25.4	417	174	0.17
Oh	1.17	0.08	0.17	40.8	34.8	510	240	0.2

Nitrogen, Phosphorus and Sulfur

Nitrogen, P and S are important primary (N, P) and secondary (S) nutrients required for plant nutrition and each forms stable covalent bonds with soil organic carbon (Tisdale et al., 1985). Microbial decomposition of soil organic compounds results in the release of these important nutrients (mineralization), a process usually only active during the summer and early fall when the soil temperatures are greater than biological zero. The majority of the Ae horizons have relatively high C/N ratios (Table 2), suggesting that soil organic matter mineralization will sustain only a low to moderate rate of N for plant growth and development. The Orthic Eutric Brunisol pedons, with Oh horizons having C/N ratios averaging 37, (Table 2) have a sufficiently high C/N ratios to limit N mineralization. The majority of the C/P and C/S ratios are greater than 140, indicating that S and P mineralization rates may be low (Tisdale et al. 1985). Because of the apparent uniformity of the parent material, vegetation and climatic conditions, it is not surprising that regression analysis shows that the N and S in the organic matter enriched surface horizons are strongly related:

$$[S] = 0.16 [N] - 0.21 \quad r^2 = 0.98.$$

Aide and Cwick (1998) have previously demonstrated that the uppermost inorganic horizons from similar soils in the study area are low in nitrate-N, Bray-1 phosphorus and sulfate-S.

Alkali and Alkaline Earth Elements in the Bm and C Horizons from the Six Brunisol Soils

Calcium, Mg, Na and K are the dominant alkali and alkaline earth elements, with smaller concentrations of Ba, Sr and Rb (Table 3). Calcium concentrations are positively related to Sr ($r = 0.90$) and Mg ($r = 0.87$), suggesting that carbonate concentrations, particularly in the lower inorganic horizons, are controlling the abundances of these elements (Kabata-Pendias and Pendias 1985). The large standard deviation of the Ca and Mg results from the decidedly more abundant Ca and Mg concentrations in the varved parent materials, indicating the leaching of these two elements from the Bm horizons.

Table 3. Elemental abundance of selected elements from the inorganic horizons of six Brunisol soils.

Element	Concentration		Element	Concentration	
	mg • kg ⁻¹			mg • kg ⁻¹	
		Standard Deviation			Standard Deviation
Na	4930	853	Al	25600	6270
K	5580	1570	Sc	6.5	1.5
Mg	17670	5930	V	61	13
Ca	25360	28200	Mn	580	119
Sr	37	13	Fe	33200	7530
Ba	160	41	Co	17	4
Ni	41	9	Cu	30	7
Zn	84	20	Y	13	3
Zr	37	13	Pb	15	4

Potassium and Na are abundant, averaging 5580 mg K • kg⁻¹ and 4930 mg Na • kg⁻¹. The concentrations of K, Na, Ba, Sr and Rb do not show any significant differences between the more acidic near-surface inorganic horizons and the deeper, more calcareous parent materials, suggesting that soil weathering and soil profile development has not been sufficiently advanced to leach or deplete these elements in the near-surface horizons. Analysis of the 23 sites selected for the geochemical baseline corroborate the alkali and alkaline earth concentration patterns of the six Brunisol pedons.

Selected Transition Metals in the Bm and C Horizons from the Six Brunisol Soils

Iron (Fe) is the dominant transitional metal in all of the Bm and varved parent materials, averaging 33200 mg Fe • kg⁻¹ (Table 3). Manganese concentrations are appreciable 580 mg Mn • kg⁻¹, followed in abundance by Zn, Cr, and V (Table 3). Transition metal concentration differences between the Bm and the varved parent materials are not evident, reflecting the limited degree of weathering and soil development.

Selected Transition Metals in the Bm and C Horizons from the 23 Baseline Soils

The abundances of various transition metals, derived from the geochemical baseline samples, lack sufficient mean separation between the Ae and the underlying horizons to support elemental depletion of the Ae horizon. Iron concentrations are positively correlated with Al ($r = 0.98$), Ba ($r = 0.90$), Co ($r = 0.93$), Cr ($r = 0.98$), Cs ($r = 0.94$), Ni ($r = 0.97$), Sc ($r = 0.89$), V ($r = 0.94$), Zn ($r = 0.97$) and Zr ($r = 0.91$). Figure 3 displays the relationships of Fe with Cr, V, Co, Ni and Zn. Manganese is positively correlated with Co ($r = 0.91$) and Zr is positively correlated with Rb ($r = 0.87$). The concentrations of these elements are largely typical for clayey materials derived from felsic materials (Kabata-Pendias and Pendias, 1985) and the positive correlations reflect the uniformity of the parent materials in a frigid climate supporting a limited degree of soil development and a narrow range of vegetation. Lanthanum and Selected Lanthanides

The REE have unique chemical characteristics and may be used as geochemical markers (Henderson, 1984; Kabata-Pendias

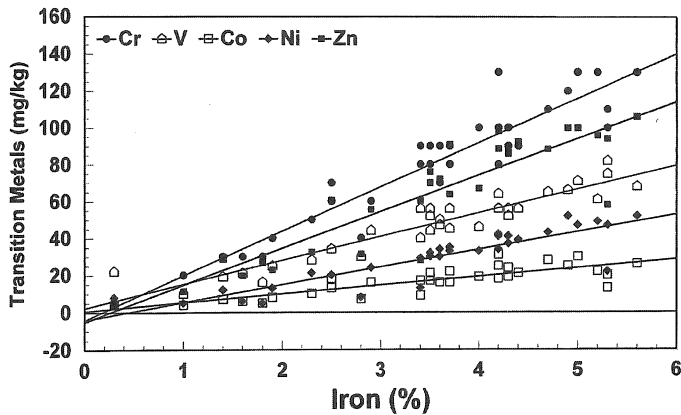


Fig. 3. Relationship of Fe to selected transition metals.

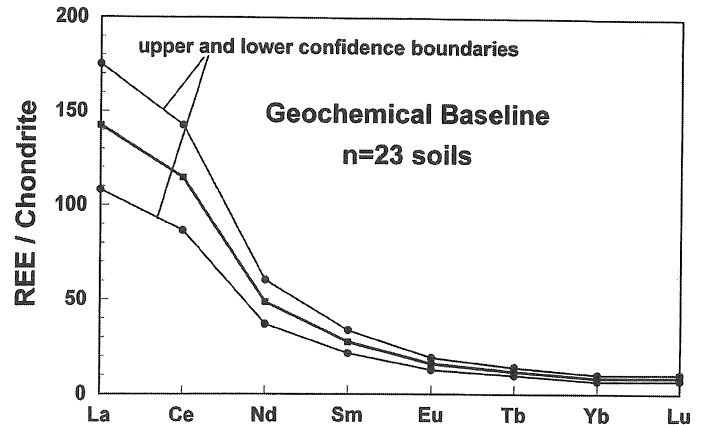


Fig. 4. Rare earth element distribution.

and Pendas 1985). The mean REE concentrations for the six Brunisol pedons (Fig. 4) are largely typical for fine-textured sediments (Kabata-Pendas and Pendas 1985; Humphris, 1984) and no significant REE concentration differences exist between the Ae and Bm horizons. The REE concentrations in the six Brunisol pedons are indistinguishable from those of the geochemical baseline series. The lack of chemical weathering and soil profile development restricts any inter-horizon transfer of the REE within an individual soil. Acidic, oxidizing conditions are known to be conducive to REE weathering, especially in the presence of organic complexing agents (Fleet 1984; Braun et al., 1993; Braun et al., 1998); however, the climatic conditions of the study area are apparently too severe to effectively deplete the Ae horizons of its REE pool. Apatite and zircon have been shown to have a substantial light REE (La to Sm) (Braun et al., 1993, 1998; Condie 1995; Henderson, 1984; Humphris, 1984) and heavy REE (Tb to Lu) (Braun et al., 1993, 1998; Condie 1995; Henderson, 1984; Humphris, 1984) complements, respectively. Apatite and zircon are commonly occurring minerals within the felsic rocks of the Canadian Precambrian Shield.

Summary

Six Eutric Brunisols were examined to determine their elemental abundances and to isolate those soil processes responsible for any significant elemental redistribution between the organic and inorganic horizons. The Brunisols have either an O - Bm - C horizon sequence or an Ae - Bm - C horizon sequence. Histic epipedons show Van Post decomposition values indicating entirely intact fibrous materials to highly decomposed organic materials lacking any recognizable fiber content. Chemical analysis of the organic fraction suggests that N, P and S mineralization rates are low; however, these low mineralization rates should not limit the productivity of the Black Spruce forests.

Soil acidification appears to be the dominant soil forming process, largely the result of the low base content and organic acid production potential of the black spruce forests. Other important soil forming processes include: development of soil structure in the Bm horizons, incipient development of an Ae

horizon, partial leaching of carbonates, humification and a low degree of Fe-oxide formation. The clay mineralogy is perceived to be largely an inherited feature.

References

- Agriculture Canada Expert Committee on Soil Survey. 1987. The Canadian system of soil classification. 2nd ed. Agriculture Canada, Ottawa, ON. Publ. 1646.
- Aide, M.T. and Cwick, G.J. 1998. Chemical weathering in soils from the glacial Lake Agassiz region of Manitoba, Canada. *Environ Geol.* 33:115-121.
- Braun, J., Pagel, M., Herbillon, A., and Rosin, C. 1993. Mobilization and redistribution of REE's and thorium in a synthetic lateritic profile: A mass balance study. *Geochim. Cosmochim. Acta* 57:4419-4434.
- Braun, J., Viers, J., Dupre, B., Polve, M., Ndam, J., and Mullier, J. 1998. Solid/liquid REE fractionation in the lateritic system of Goyoum, East Cameroon: The implication for the present dynamics of the soil covers of the humid tropical regions. *Geochim. Cosmochim. Acta* 62:273-299.
- Carter, M.R. 1993. Soil sampling and methods of analysis. Canadian Society Soil Science, Lewis Publishers, Boca Raton, FL.
- Condie, K.C., Dengate, J., and Culliers, R.L. 1995. Behavior of rare earth elements in a paleoweathering profile on granodiorite in the Front Range, Colorado, USA. *Geochim. Cosmochim. Acta.* 59:279-294.
- Fleet, A.J. 1984. Aqueous and sedimentary geochemistry of the rare earth elements. Page 343-373 in P. Henderson, Ed. *Rare earth element geochemistry*. Elsevier, NY.
- Henderson, P. 1984. The mobility of the rare earth elements in the crust. Page 317-340 in P. Henderson, ed. *Rare earth element geochemistry*. Elsevier, NY.
- Humphris, S.E. 1984. The mobility of the rare earth elements in the crust. Page 317-340 in P. Henderson, ed. *Rare earth element geochemistry*. Elsevier, NY.

- Kabata-Pendias, A. and Pendias, H. 1985. Trace elements in soils and plants. 2nd ed. CRC Press, Boca Raton, FL.
- Kaszycki, C.A. 1989. Surficial geology and till composition of northwestern Manitoba. Geological Surv. Canada Open File 2118.
- Klassen, R.W. 1983. Lake Agassiz and the late glacial history of northern Manitoba. Page 97-115 in J.T. Teller and L. Clayton, eds. Glacial Lake Agassiz. Geological Association of Canada Special Paper 26.
- Klassen, R.W. 1986. Surficial geology and till composition of north-central Manitoba. Memoir 419. Geological Survey Canada, Ottawa, ON.
- Larsen, J.A. 1980. The boreal ecosystem. Physiological ecology—A series of monographs, texts and treatises. Academic Press, NY.
- McKeague, J.A. and M.S. Wolynetz. 1980. Background levels of minor elements in some Canadian soils. *Geoderma* 24:299-307.
- Mermut, A.R., Jain J.C., Song, L., Kerrich, R., Kozak, L., and Jana, S. 1996. Trace element concentrations of selected soils and fertilizers in Saskatchewan, Canada. *J. Environ. Qual.* 25:845-853.
- Tisdale, S.L., Nelson, W.L., and Beaton, J.D. 1985. Soil fertility and fertilizers. Macmillan, NY.

Determining the Spring to Summer Transition In the Missouri Ozarks Using Synoptic Scale Atmospheric Data

Christopher W. Ratley and Anthony R. Lupo

Department of Atmospheric Sciences, University of Missouri-Columbia, 389 Mc Reynolds Hall Columbia, MO 65211

Martin A. Baxter

Department of Earth and Atmospheric Science, Saint Louis University, 3507 Laclede Avenue, St. Louis, MO 63303

Abstract: There is abundant anecdotal evidence available to suggest that the transition from a spring to summer season flow regime is often quite abrupt. This same transition renders long-range forecasting problematic as the forecast time period crosses through the spring and summer seasons. Despite these problems, the transition from spring-to-summer flow regimes is a problem that has not been examined in detail in the published literature. In this study, the transition is examined from a regional perspective over a 20-year period (1981–2000) and includes the development of a criterion for identifying the transition based on using routinely available synoptic observations. Within the East-central Ozarks region of Missouri, the transition from spring-to-summer season flow regimes is often abrupt, and is identified as occurring in mid-June. The transition could also be identified for the entire Northern Hemisphere using the 500 hPa wave amplitude index for some years during the 1980's. The results found here are consistent with the results of the one other study found in the literature that also addresses the spring-to-summer transition issue for the entire Northern Hemisphere. Additionally, this study found that the average date of summer onset in the region is June, and the 20-year set of summer onset dates was normally distributed with respect to this mean. It was also shown that there is an abrupt change in the average period between heavy precipitation events. Finally, it is demonstrated that late arriving summers are generally associated with a transition in the phase of the El Nino and Southern Oscillation (ENSO), especially the La Nina phase, while early arriving summers are generally associated with steady-state ENSO conditions.

Introduction

There is anecdotal evidence available suggesting that the transition from spring-to-summer flow regimes in the Northern Hemispheric troposphere can occur abruptly. However, this transition is a topic that has not been studied very frequently. A web-based search of all the American Meteorological Society journals from 1944 to 2002¹ revealed that there was only one article (Nogues-Peagle and Mo, 1987) published that devotes the full article to the subject, and only 171 articles that discuss the concept at all (e.g., O'Lenic and Livezey, 1989). Using spherical har-

monics to decompose global fields of the geostrophic streamfunction (ψ), velocity potential (χ), and height (z), Nogues-Peagle and Mo (1987) demonstrate that this spring-to-summer transition occurred rapidly during the May to July 1979 period via the amplification of planetary-scale waves as represented using the four lowest harmonics. Many other articles mention this rapid seasonal transition within the context of the difficulty the transition creates for the analysis of observations (e.g., O'Lenic and Livezey, 1989) or the difficulty such rapid transitions in the large-scale flow regimes present to model simulations or forecasts (e.g. Palmer, 1988).

The large-scale flow over the North American Continent has long been shown to be influenced by an atmospheric teleconnection pattern (e.g., Wallace and Gutzler, 1981) known as the Pacific North American (PNA) teleconnection. This teleconnectivity, which has four centers of action associated with it, is most likely the result of Rossby wave excitation by tropical convection in the central Pacific Ocean Region and the subsequent propagation of these waves downstream (e.g., Ambrizzi and Hoskins, 1996). Also, the PNA pattern has been shown to have several modes (e.g., Keables, 1992) and the predominance of particular modes has been shown to be related to the phase of the El Nino and Southern Oscillation (e.g., Kung and Chern, 1995). However, this teleconnectivity has been shown to be strongest during the winter season.

The transition to a summer regime over North America has been investigated with respect to large-scale circulation shifts which lead to, for example, the onset of the southwest monsoon in Arizona, New Mexico, and Northwest Mexico (e.g., Higgins et al., 1997). The Southwest Monsoon has also been shown to be modulated by an oscillation linked to tropical convection and with a period of 3 to 4 weeks (Mo, 2000). This oscillation is also partly linked to the Madden Julian Oscillation (MJO), which is a 30–60 day oscillation in tropical convection linked to an equatorially trapped Kelvin wave. Mo (2000) also demonstrates that this oscillation propagates eastward into the Great Plains and Midwestern States as well. Occasionally, the summer PNA pattern over North America will imply a shorter wavelength in this

1. The internet address for the American Meteorological Society is: www.amet-soc.org/AMS/. This search was conducted on the journals homepage using the words "spring to summer transition."

pattern than described above and be associated with five centers of action. This type of activity has been shown to predominate over North America during dry summers (e.g., Namias, 1982, 1983), and in association with continental region blocking (e.g., Lupo and Bosart, 1999).

It has been observed that in Central Missouri the sultry, oppressive days of the summer season frequently make an abrupt entrance, often in mid-June. The mild and frequently wet pattern of the Midwest spring evolves quickly into a prolonged period of intense heat and humidity. The northward migration of the East Pacific and Bermuda highs and the mid-latitude storm track along with the development of a thermal trough ("heat low") in the desert southwest and a "plateau high" (see Tang and Reiter, 1984) over the four corners region accompany the transition to a summer like flow regime. In the Midwest, the enhanced northward flow of moist air from the Gulf of Mexico associated with the westward extension of the Bermuda high provide a hot, humid regime with infrequent periods of precipitation, as the mid-latitude jet resides over southern Canada (Bryson and Hare, 1976).

Thus, the spring-to-summer season transition in the East Central Ozarks of Missouri, its character, timing, and predictability were the focus of this research. It will be demonstrated that this transition is often abrupt, but identifiable using a set of criterion based on routine synoptic observations. This paper will review the:

- (1) criteria chosen for determination of summer onset in Mid-Missouri,
- (2) relationship of summer onset to large-scale flow regime changes,
- (3) relationship of summer onset dates to precipitation climatology,
- (4) a discussion of the results.

Data and Methods

The Missouri River to the north, Mississippi River to the east, Arkansas border to the south, and Western Ozarks region to the west outline the region of study (Fig. 1). Much of the karst topography of the East Central Ozarks is covered with oak, hickory forest with few urban areas intermixed, St. Charles being the exception, and low population density. Nine National Weather Service (NWS) Cooperative Stations sites were chosen for daily temperature and precipitation data analysis.

This region was chosen for study since there are several surface stations maintained by the Missouri Climate Center that are also located in this region. This data could be used if needed for quality control. Also, for each NWS cooperative station location there is climatic data available from 1918 to the present. In the paper, the data from Jefferson City is used to represent the East Central Ozark region. An analysis of summer season precipitation using principal components analysis (PCA) by Palecki and Leathers (2000) suggests that this station would be representative of the summer climate of the East Central Ozark region, at least for this initial analysis. Additionally, the study by Park and Kung (1988) and Lee and Kung (2000) using similar techniques sug-

gest that interannual variations of temperature across the region would behave similarly.

The daily temperature records from April 1 to September 1 at Jefferson City are analyzed and the following criteria are applied in order to determine the summer transition date:

- (1) the beginning of the first period of fifteen consecutive days with mean temperature exceeding 21.1° C (70° F) and at least ten of those days exceeding 23.9° C (75° F).
- (2) the beginning of the first period of fifteen consecutive days with maximum temperature exceeding 25° C (77° F) and at least 10 of those days above 27.8° C (82° F).

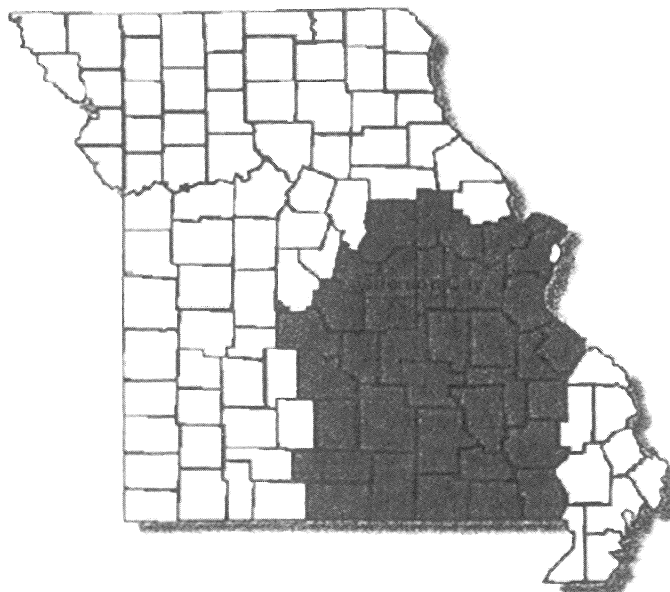


Figure 1. A map of Missouri, including the region of study (grey shading).

These means were chosen on the basis that the base thresholds are whole numbers close to one standard deviation below the monthly June means. Thus, the summer transition is not based on numbers that are unrealistically high and which might result in a summer transition not being identified at all. Also, by examining 15-day averages, the synoptic and diurnal variations are filtered out (e.g., Yarnal, 1993) and this guarantees that the largest-scale components are captured.

Various types of manually derived climatological classification criterion, such as these two above, do have some shortcomings (e.g., Yarnal, 1993). It was found that the transition date identified by the first criterion was sometimes sensitive to orographic influences, and in particular cool air drainage influencing the daytime mean temperatures. Thus, the second criterion was added in order to alleviate this problem. Also, this indicates that care should be taken in choosing surface stations that have similar surroundings (i.e., rural versus urban stations, see discussion above). Additionally, relating the planetary-scale to the synoptic and meso-scale can be problematic due to the fact that there are complex scale interactions which cannot be accounted for using these simple techniques (e.g., Yarnal, 1993) and may be highly non-linear (e.g., Yarnal, 1993; Lupo, 1997). Lastly, studies of

this type may only be applicable in the region of study (e.g., Yarnal), even though the analysis of Palecki and Leathers (2000) and others would suggest would be applicable across most of the eastern two-thirds of the state. This study attempts to address the issue by using statistical parameters in the definitions discussed above. However, it is beyond the scope of this particular study to examine the universality of the proposed spring to summer transition criterion.

In order to address scale issues by bridging the planetary and synoptic-scales, a third criterion is also introduced that is based on the pressure (mass) field. The 500 hPa height data for each summer were examined to locate the initial date of a period persisting ten days or longer in which these heights are in excess of 5820 meters. The rationale for this choice of contour is that the 5820m contour is quite often located along the southern flank of the strong mid-latitude height gradients and represents the mean 500 hPa contour across Central Missouri in June (e.g., Bentley and Mote, 1998). Thus it is suggested that the '582' contour represents a convenient cutoff between the more baroclinic mid-latitude flow and the quasi-barotropic regime which characterizes subtropical flows. Again, a longevity criterion is also paired with the height criterion to filter out synoptic-scale variations.

The frequency of significant precipitation (greater than or equal to 0.25 inches) events prior to and after the estimated summer onset date is inferred from the precipitation period in columns 6 and 7 of Table 2. The number of days between quarter inch rainfall events was averaged from the last event in April to the event prior to the selected date for the seasonal transition. Subsequent intervals to the first quarter inch precipitation event in August are used to calculate post onset period. Precipitation periods reflect the average across the 9 cooperative stations used in the region. Significant precipitation period was examined as opposed to precipitation amounts, since precipitation during the spring and summer within the Eastern Ozarks Region is primarily convective in nature, and thus locally intense precipitation rates can contribute to inflated precipitation amounts even though fewer events may occur. Also, the period with which precipitation occurs can be correlated, at least partially with the period or frequency of the passage of synoptic-scale waves or disturbances through the study area. Finally, for agricultural purposes, the frequency of heavy precipitation is an important variable, since prolonged dry spells may be more detrimental to crop growths and yields than more frequent rain events (A. Akyuz, State Climatologist, Personal Communication, 2002), even if these latter events result in lighter rains.

The interannual variability of the onset of the summer transition with respect to the phase El Nino and Southern Oscillation (ENSO) is also studied here. The Japan Meteorological Agency (JMA) ENSO Index was used in this study. A list of El Nino (EN), La Nina (LN), and Neutral (NEU) years (Table 1), as well as a more detailed description of the JMA ENSO Index, can be found by accessing the Center for Ocean and Atmospheric Prediction Studies (COAPS) website². In summary, the index classifies years as EN, LN, and NEU based on 5-month running-mean Pacific Ocean basin sea surface temperatures (SST) anomaly thresholds bounded by the region 4° N, 4° S, 150° W, and

90° W. The defined region encompasses both the Nino 3 and 3.4 regions in the central and eastern tropical Pacific (e.g., Pielke and Landsea, 1999). The SST anomaly thresholds used to define EN years are those greater than or equal to +0.5° C, less than or equal to -0.5° C for LN years, and NEU otherwise. For classification as an EN or LN year, these values must persist for 6 consecutive months including October, November, and December. The JMA

Table 1. A list of years examined in this study separated by ENSO phase.

La Nina (LN)	Neutral (NEU)	El Nino (EN)
1970	1974	1969
1971	1977–1981	1972
1973	1983–1985	1976
1975	1989–1990	1982
1988	1992–1996	1986–1987
1998–1999	2000	1991
		1997

Table 2. Summer transition period estimated according to maximum temperature, mean temperature and 500 millibar height criteria as well as estimated date. The precipitation (> 0.25 inches per day) prior to and post onset of summer data and the El Niño - Southern Oscillation phase according to the JMA criteria for the summer are listed in the last three columns (1=La Niña, 2=Neutral, 3=El Niño). The numbers in the header block are column numbers

Summer Transition Criteria Dates					Precipitation Period (days)		ENSO
1	2	3	4	5	6	7	9
YR	MxT	MnT	500H	Date Selected	PRE	POST	
2000	7-2	7-2	7-1	7-1	7.5	8.1	1
1999	6-19	6-21	6-3	6-19	7.0	20.8	1
1998	6-17	6-17	6-17	6-17	5.7	11.3	3
1997	6-15	6-16	6-9	6-19	7.6	10.1	2
1996	6-12	6-12	6-3	6-13	6.9	6.9	2
1995	6-13	6-15	7-7	6-15	6.6	19.5	2
1994	6-11	6-11	6-13	6-11	10.0	7.8	2
1993	6-8	6-10	6-11	6-10	6.9	5.9	2
1992	6-23	6-29	7-1	6-28	6.7	9.0	3
1991	5-21	5-21	6-6	5-21	2.5	10.0	2
1990	6-6	6-7	6-5	6-6	5.2	9.7	2
1989	6-17	6-19	6-19	6-19	9.8	8.9	1
1988	6-6	6-12	6-10	6-10	9.7	23.7	3
1987	5-26	6-6	6-5	6-5	11.0	10.7	3
1986	6-4	6-14	6-16	6-13	4.0	12.8	2
1985	6-19	6-29	7-7	6-29	4.0	9.8	2
1984	5-31	6-3	6-9	6-3	7.5	15.6	2
1983	6-15	6-18	7-1	6-20	7.5	22.7	3
1982	6-20	7-2	6-29	6-27	3.5	5.7	2
1981	6-18	6-23	6-21	6-21	6.0	4.3	2

2. The COAPS website is at: <http://www.coaps.fsu.edu>.

ENSO criterion defined the El Niño year as beginning on 1 October of the previous year. Thus, ENSO year 1970 begins in October of 1970 (Table 1) and ends in September 1971. Table 2 classifies the summer-season ENSO phase by labeling the calendar year. The JMA definition, however, has been modified in other studies (e.g., Lupo and Johnston, 2000) in order that the El Niño year commenced with the initiation of the hurricane season (1 June), or the blocking year (1 July by Wiedenmann et al., 2002). Such modifications can be justified since El Niño conditions typically begin to set in before 1 October, and 1 October is close to the climatological peak of hurricane season (10 September).

In order to determine whether the Northern Hemisphere flow undergoes a transformation in mean energy state, the wave amplitude index (WI) was used (Hansen, 1986; Sutera, 1986). The wave amplitude index is expressed as:

$$WI = \left(\sum_{m=2}^4 2Z_m^2 \right)^{1/2} \quad (1)$$

where Z_m represents the Fourier coefficients for the zonal wave number m . Z_m was calculated by using the twice daily 500-hPa heights from the European Centre for Medium Range Forecasting (ECMWF). For each map-time (0000 UTC and 1200 UTC), the 500 hPa heights from 1 January, 1980 to 31 December 1988 were averaged with respect to latitude from 22.5° N to 77.5° N, and then Fourier decomposed in the zonal direction. The result is WI, which is in reality the square root of the height variance and not the amplitude. The amplitude can be obtained by multiplying by the square root of 2 (Hansen, 1986). The resulting time-series was then filtered to remove high (periods less than 5 days) and very low frequency (e.g., the annual cycle) variability, again using Fourier transformation and re-synthesizing the data after "zeroing out" the unwanted frequencies (Hansen, 1986; Sutera, 1986). Plotting these values on a histogram yields a probability density distribution that is clearly bimodal (see Hansen, 1986 or Sutera, 1986 for more detail) with one peak corresponding to a "low amplitude" (mode 1) flow regime, and the other to a "high amplitude" (mode 2) flow regime. While recent studies attempt to demonstrate using newer statistical methods that these results are not statistically robust (Nitsche et al., 1994) and should be viewed with caution, previous studies of the physical behavior of the solutions to the primitive equations using low-order models (e.g., Lorenz, 1963; Haines and Holland, 1998) suggest the "vacillation" behavior in the planetary-scale flow is quite plausible. Also, such behavior has been noted and observed in planetary-scale flows by forecasters since the late 1950s.

Analysis

a. Results using the criterion

The evolution to the summer season typically occurs over a period greater than 3 to 5 days, however abrupt changes do occur. For example, increases of 90 meters and 180 meters in the 500 hPa height fields over the region occurred in a 24 hour period during the selected summer onset dates for 1997 and 1998 respectively.

In 9 of the 20 years examined in Table 1, the three summer criteria indicated summer onset within the same +/- 5 calendar-day interval from the chosen onset date. In the remaining years, the summer onset date was chosen where two of the three parameters were in close agreement. If there was significant separation of similar magnitude in all the dates indicated, the onset day was chosen within the time period indicated by averaging the dates. The 20-year mean date for the onset of summer was calculated to be June 15, and mid-June would be in agreement with the results of Nogues-Peagle and Mo (1987) who found the rapid spring-to-summer season transition occurred during the June 1979 period. Sixty percent of the summer onset dates occurred between June 10–20, with twenty percent occurring prior to June 10 and twenty percent occurring after June 20. The standard deviation of the sample dates is roughly +/- 10 calendar-days, and 65% of the onset dates occur between June 5 and June 25. There were 3 occurrences earlier and four later than this interval, and, thus, the distribution was consistent with that of normally distributed data, in spite of the small sample acquired here.

In examining each criterion separately (Table 2) and determining the reliability of each to identify the final transition date, it can be shown that the daily mean temperature was the most reliable parameter. If reliability is gauged by stipulating that the criterion and the final transition date selected were within 2 days of each other, the mean temperature criterion was reliable for 18 of the 20 years. The maximum temperature and 500 hPa height contour criteria were reliable for only 10 and 9 years, respectively and can be thought of as criterion which refined the selection of the final date.

b. Analysis of the planetary-scale flow regime

The results above suggest that the spring-to-summer season transition in the East Central Ozarks Region is identifiable using routinely available observational synoptic data. Since the criterion presented here is regional, it is reasonable to assume that the spring-to-summer season transition would not necessarily correspond to that identified in the hemispheric flow regime, if indeed the transition can be identified at all at the largest scales. Fig. 2 presents plots of WI for the May through August period for the years 1981–1988 using ECMWF data. The vacillation of Northern Hemisphere heights between mode 1 and mode 2 episodes occurring at irregular intervals can easily be identified (e.g., Lorenz, 1963, Hansen 1986, Sutera, 1986). A general downward trend is evident in each period except for the 1988 late spring and summer period (Fig. 2h). The years 1981, 1984, 1985, and 1987 (Figs 2a, d, e, and g) reveal that abrupt changes in the index value, which is proportional to the kinetic energy of the geostrophic wind. For the year 1984, this sudden decrease in WI occurs early in the period, while for other three years this change occurred midway through the displayed period. Again, if these represent the identification of an abrupt transition from the spring to summer season as represented by Northern Hemisphere planetary-scale kinetic energies, the timing of these "shifts" (mid-June) would be consistent with the findings of Nogues-Peagle and Mo (1987).

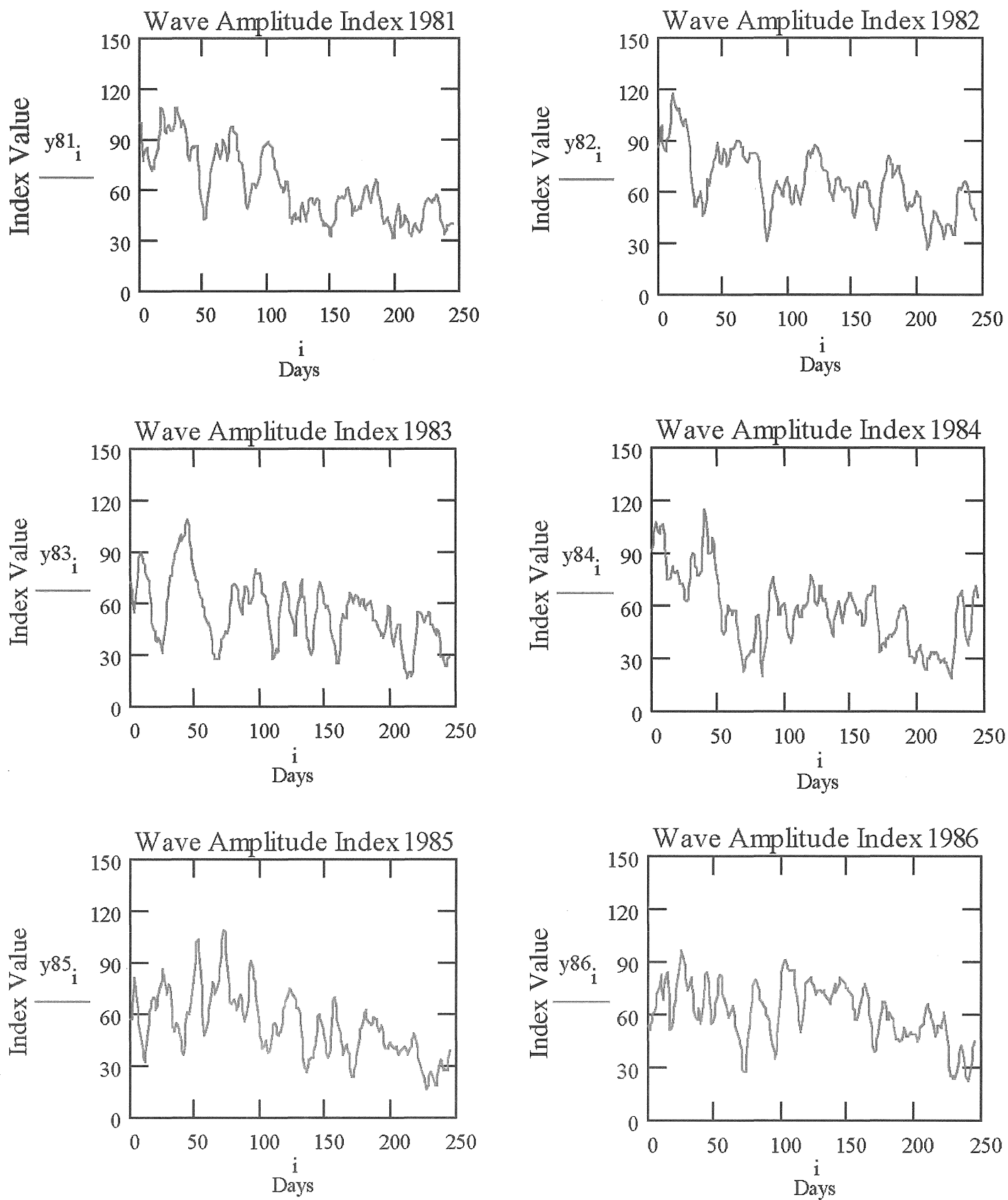


Figure 2. Plot of the twice daily wave amplitude index values versus time (May 1–31 August) for the year a) 1981, b) 1982, c) 1983, d) 1984, e) 1985, f) 1987, and h) 1988.

In 1981 (1984) (Figs. 2a and d), the abrupt change in the value of WI occurs shortly after June 20 (around May 25), and our criterion identifies the local spring-to-summer season transition to be June 21 (June 3) (Table 2). For each of these years, the spring-to-summer season transition dates as identified by our criteria are close together and in each case two of the three parameters are within 3 days of each other. For the year 1985 (Fig. 2e), an abrupt change in WI occurred shortly after June 20, however, there was substantial spread among the spring-to-summer season transition date selected by each criterion. Even so, the final date selected for the transition date appeared to occur within approximately one week to ten days of the change in WI. In 1987 (Fig. 2g), an abrupt change in WI occurs close to the end of June while our criterion identifies the spring-to-summer season transition in early June.

For the remaining years, where a gradual decrease or no change in WI is evident (Figs. 2b, c, f, and h), the spring-to-summer transition was easily identified in three of the four years as well. During 1983, there was substantial spread in each of these criteria, while the WI values decreased gradually throughout the period. While the above results constitute a small sample, it is encouraging to note that for three of the eight years, an abrupt change in the kinetic energy of the hemispheric flow reasonably matched the identification of the spring-to-summer season transition for the East Central Ozarks Region of Missouri using daily observations. This occurs despite the fact that an abrupt shift from spring-to-summer season was not consistently identifiable using the hemispheric data. Finally, attempts to find a correspondence between the spring-to-summer season transition and other parameters, such as the occurrence of Northern Hemisphere blocking (Wiedenmann et al., 2002) failed to reveal any further insight.

c. Precipitation Frequency

For 16 of the 20 years, the heavy precipitation frequency diminished after the summer onset date (Table 2), though in some cases summer precipitation totals exceeded those of spring due to intense though infrequent rainfall events. In Table 2, a lower (higher) number corresponds to an increase (decrease) in heavy precipitation frequency. During the four years in which the precipitation frequency increased, the spring-to-summer season transition was identified as occurring early (1993, 1994) and late (1981, 1989) for two years each. The 20-year mean shows that the heavy precipitation frequency was 6.8 days before the summer transition, but 11.6 days after the transition. This result would be consistent with the poleward migration of the polar front jet stream and storm track through the Midwestern US and into Southern Canada during April to July period.

d. Interannual Variability in Summer Onset Dates

The interannual variability of summer onset dates was examined with respect to the phase ENSO. As mentioned earlier, the ENSO phase was identified for each summer season using the JMA criterion. However, since El Nino and La Nina conditions tend to set in gradually and emerge strongly during the fall months, classification of summer seasons is not straightforward (e.g., Renwick and Revell, 1999; Lupo and Johnston, 2000;

Wiedenmann et al., 2002). Thus, summer seasons here are identified using the JMA criterion for the current ENSO year (Table 2) and the following ENSO year. In this way, summer seasons in which ENSO is transitioning phases can be differentiated from extended periods of quasi-steady state conditions (Table 3). Additionally, spring-to-summer season transitions occurring before (after) June 15 are considered to be early (late) transitions, and 10 study periods each were classified as early or late onsets.

For summers classified as early transitions (Table 3) in the East Central Missouri Ozarks region, 7 of these involved periods in which the phase of ENSO was steady state. For 6 of these summer transition periods, the summer season was classified as "neutral" and the upcoming fall "neutral" as well (here we adopt the notation convention "steady state neutral"), while one summer period (1987) was associated with steady state El Nino conditions. Two summers were also associated with the transition from the neutral phase into El Nino conditions, or the onset of El Nino. Thus, 90% early summer transition during this 20 year period were associated with steady state El Nino or neutral conditions, or the onset of El Nino out from neutral conditions.

Conversely, for summers classified as later onset dates (Table 3) within the study region, only three were associated with steady state ENSO conditions. This includes one summer season classified as steady state La Nina conditions (1999), and two which were steady state neutral conditions. All other late arriving summers were associated with a change in ENSO phase. This subset includes 3 out of 4 phase changes in ENSO involving the La Nina phase. Thus, the onset or persistence of La Nina conditions during this 20-year period was associated with late arriving summers. Additionally 80% of the summers in this category involved either the La Nina phase or an ENSO phase transition.

Table 3. Summer onsets identified as an early or late onset by year and ENSO phase (during the summer of that year and the upcoming year classification).

Early		Late	
Year	ENSO phase	Year	ENSO phase
1996	neu-pre neu	2000	LN-pre neu
1995	neu-pre neu	1999	LN-pre LN
1994	neu-pre neu	1998	EN-pre LN
1993	neu-pre neu	1997	neu-pre EN
1991	neu-pre EN	1992	EN-pre neu
1990	neu-pre neu	1989	LN-pre neu
1988	EN-pre LN	1985	neu-pre neu
1987	EN-pre EN	1983	EN-pre neu
1986	neu-pre EN	1982	neu-pre EN
1984	neu-pre neu	1981	neu-pre neu

e. Interannual variability in precipitation frequencies

Seasons that involved early transitions from spring-to-summer the average change in frequency of significant precipitation was slightly greater than that for summers associated with a later transition date (7.0 to 12.3 days for early versus 6.6 to 10.9 for late arriving summers). This would suggest, that else being equal, summers with later season transition dates would be wetter in

general than summers with early season transition dates. The higher frequency of rain events would mean more chances for rain. The average rainfall in early arriving summers versus late arriving summers at the Columbia Regional Airport (CRA) was 12.23 inches and 13.98 inches, respectively. While this difference is close to two inches, the number is not statistically significant owing to the large standard deviations in precipitation amounts (interannual variability) and the small samples compared. Also, while the CRA is located in a county adjacent to the study region, the interannual variations should behave in a similar manner.

It has been suggested that in the East Central Ozarks region, La Nina summers tend to be drier than El Nino summers. The summers of 1988 and 1999 were two of the driest summers across this region in the latter portion of the 20th century. Given the difficulty in identifying the summer season with one phase or the other, the precipitation period in El Nino and El Nino transition summers are compared to those of La Nina and La Nina transition summers. For El Nino and El Nino transition summers the precipitation frequency was higher than for La Nina and La Nina transition summers. The precipitation period was 6.5 and 12.9 days for the former, and 7.9 and 14.6 days for the latter, respectively. However, comparing the rainfall totals from the Columbia Regional Airport reveals that the El Nino summers were drier than La Nina summers (10.2 inches of rain versus 12.44 inches, respectively). Thus, it is implied that during El Nino (La Nina) summers, there was more (fewer) rain events with lighter (heavier) rainfall totals. This comparison presents an illustration of the possible problem in examining rainfall total amounts to uncover interannual variability related to ENSO versus significant rainfall frequency or periods. Again, for agricultural purposes, the La Nina summers represent a less ideal rainfall distribution.

However, the above stratification included some summers (e.g. 1988 and 1998) in both data sets. In order to remove this overlap, only summers prior to onset of El Nino or La Nina, or summer seasons that occurred during prolonged El Nino or La Nina conditions were compared. This stratification effectively uses the summer season ENSO classification scheme of Renwick and Revell (1999), Lupo and Johnston (2000), or Wiedenmann et al. (2002). There was no tendency for these El Nino (or El Nino onset) (1982, 1986, 1987, 1991, 1997) or La Nina (or La Nina onset) summers (1988, 1998, 1999) to arrive early or late (Table 2), however, this 20-year sample is very small. Even so, the spring-to-summer transition results in an even greater lengthening of the precipitation period for the La Nina summers (7.5 days spring to 18.6 days summer), than for El Nino years (5.7 days spring to 9.9 days summer).

f. interannual variations in summer temperatures

An examination of mean summer season surface temperatures in the East Central Ozarks Region were compared with the summer onset dates in order to determine if there were any correlations. The 30-year (1971 – 2000) mean summer season temperatures were 75.5° F and the standard deviation was 1.6 oF. Summers associated with an early onset date were warmer than

those with a later onset date (76.1° F versus 74.7° F, respectively), but these values are not significantly different from the long-term mean or each other at acceptable levels of statistical confidence. Also, the average temperature for La Nina summers was 76.6° F, while the mean temperature for El Nino summers was 75.6° F. While none of these figures are statistically significant, summers that are drier or associated with longer dry spells (e.g., La Nina years as shown in section 3d), would be expected to be associated with warmer surface temperatures. These summers would be associated with more insolation and less of this insolation would be spent drying the ground. Earlier studies (e.g., Namias, 1982, 1983) associated warm dry summers in middle of North America with strong middle and upper tropospheric ridging over the continent.

Summary and Conclusions

The transition to the summer season in the East Central Missouri Ozarks commences with a marked and oftentimes abrupt increase in temperature and dew point and a marked decrease in precipitation. Summer onset was identified as early as May 21 and as late as July 1 in the period 1981 to 2000 and using routinely available synoptic observations, though the typical transition period was June 10 to 20, averaging around June 15. Despite the problems outlined in designing climatological classification schemes similar to the one proposed here (e.g., Yarnal, 1993). These results are consistent with the only other published study that could be found in the literature regarding the spring to summer season transition. A comparison to the possible identification of the hemispheric spring-to-summer season transition using the Wave Amplitude Index (Hansen, 1986) was also performed. These results were also somewhat consistent with those of Nogues-Peagle and Mo (1987).

The spring-to-summer season transition was also shown to be associated with a dramatic increase (decrease) in the period (frequency) of significant precipitation amounts. However, there was no statistically significant tendency for differences in precipitation frequency for early versus late arriving summers. An examination of interannual variations as related to ENSO revealed that early (late) arriving summers were commonly associated with steady state (transitioning) ENSO phase conditions, and La Nina summers frequently were also late arriving. Additionally, there was a tendency for La Nina summers to be associated with much lower precipitation frequencies than El Nino summers. These corresponded to years with early summer onsets being warmer on average than those with a later onset date, and La Nina summers were warmer than El Nino summers by one degree Fahrenheit. Thus, when considering precipitation distributions and temperatures, La Nina summers in the East central Ozarks region are more detrimental to agricultural interests here. While none of these results are statistically significant owing to the short period of study (20-years), a longer period of study was not done due to questions about the reliability of earlier data used in this region of study. Thus, obtaining a longer period of record in order to determine if the results found here will withstand rigorous statistical testing will take some years to acquire.

Relationships between the transition to summer in the East Central Missouri Ozarks, and the onset of the Southwest Monsoon, the Southern Oscillation phase, the Pacific North American and North Pacific Oscillation patterns, seasonal snow cover depletion, and the character of the summer itself will continue to be explored.

Acknowledgments

The authors wish to thank Mrs. Sharon Burnham for preparing and editing the text, and Mrs. Tanya Akyüz for preparing some of the figures and tables. We would also like to thank Dr. Adnan Akyüz (Missouri State Climatologist) and Dr. Patrick Guinan (Extension State Climatologist) for their helpful insights and discussions. The authors are also indebted to the anonymous reviewer whose comments were very helpful in improving this manuscript.

References

- Ambrizzi, T., and B.J. Hoskins, 1997: Stationary Rossby-wave propagation in a Baroclinic Atmosphere. *Quart. J. Roy. Meteor. Soc.*, 123, 919–928.
- Bentley, M. L., and T. Mote, 1998: A Climatology of Derecho-Producing Mesoscale Convective Systems in the Central and Eastern United States, 1986-95. Part 1: Temporal and Spatial Distribution. *Bull. Amer. Meteor. Soc.*, 79, 2527–2540.
- Bryson, R. A., and F.K. Hare, eds., 1976: *The Climates of North America. World Survey of Climatology*, vol. 11, Elsevier, New York.
- Haines, K., and A.J. Holland, 1998: Vacillation Cycles and Blocking in a channel. *Quart. J. Roy. Meteor. Soc.*, 124, 873–897.
- Hansen, A.R., 1986: Observational characteristics of atmospheric planetary waves with bimodal amplitude distributions. *Adv. Geophys.*, 29, 101–134.
- Higgins, R.W., Y. Yao, and X.L. Wang, 1997: Influence of the North American Monsoon System on the U.S. Summer Precipitation Regime. *J. Climate*, 10, 2600–2622.
- Keables, M.J., 1992: Spatial variability of the mid-tropospheric circulation patterns and associated surface climate in the United States during ENSO winters. *Physical Geog.*, 13, 331–348.
- Kung, E.C., and J.-G. Chern, 1995: Prevailing anomaly patterns of the Global Sea Surface temperatures and tropospheric responses. *Atmosfera*, 8, 99–114.
- Lee, J.-W., and E.C. Kung, 2000: Seasonal-range forecasting of the Ozark climate by a principal component regression scheme with antecedent seas surface temperatures and upper air conditions. *Atmosfera*, 13, 223–244.
- Lorenz, E.N., 1963: Deterministic nonperiodic flow. *J. Atmos. Sci.*, 20, 130–141.
- Lupo, A.R., 1997: A diagnosis of two blocking events that occurred simultaneously over the mid-latitude Northern Hemisphere. *Mon. Wea. Rev.*, 125, 1801–1823.
- Lupo, A.R., and L.F. Bosart, 1999: An analysis of a relatively rare case of continental blocking. *Quart. J. Roy. Meteor. Soc.*, 125, 107–138.
- Lupo, A.R., and G. Johnston, 2000: The variability in Atlantic Ocean basin hurricane occurrence and intensity as related to ENSO and the North Pacific Oscillation. *Nat. Wea. Dig.*, 24:1, 3–13.
- Mo, K., 2000: Intraseasonal modulation of summer precipitation over North America. *Mon. Wea. Rev.*, 128, 1490 – 1505.
- Namias, J., 1982: Anatomy of great plains protracted heat waves (especially the 1980 U.S. summer drought). *Mon. Wea. Rev.*, 110, 824–838.
- Namias, J., 1983: Some causes of the United States drought. *J. Clim. and Appl. Met.*, 22, 30–39.
- Nitsche, G., C. Kooperberg, and J.M. Wallace, 1994: Is there evidence of multiple equilibria in planetary-wave amplitude? *J. Atmos. Sci.*, 51, 314–322.
- Nogues-Peagle, J. and K. Mo, 1987: Spring-to-summer transitions of global circulations during May-July 1979. *Mon. Wea. Rev.*, 115, 2088–2102.
- O’Lenic, E.A. and R.E. Livezey, 1989: Relationships between systematic errors in Medium Range Numerical Forecasts and some of the principal modes of low-frequency variability of the Northern Hemisphere 700 mb circulation. *Mon. Wea. Rev.*, 117, 1262–1280.
- Palecki, M.A., and D.J. Leathers, 2000: Spatial modes of drought in the central United States. *Preprints of the 12th Conference on Applied Climatology*, 8–11 May, 2000, Asheville, NC.
- Palmer, T., 1988: Medium and extended range predictability and stability of the Pacific/North American mode. *Quart. J. Roy. Meteor. Soc.*, 114, 691–713.
- Park, C.-K., and E.C. Kung, 1988: Principal components of the North American summer temperature field and the antecedent oceanic and atmospheric condition. *J. Meteor. Soc. Japan*, 66, 677–690.
- Pielke, R.A., and C.N. Landsea, 1999: La Nina, El Nino, and Atlantic hurricane damages in the United States. *Bull. Amer. Meteor. Soc.*, 80, 2027–2033.
- Renwick, J.A., and M.J. Revell, 1999: Blocking over the South Pacific and Rossby Wave Propagation. *Mon. Wea. Rev.*, 127, 2233–2247.
- Sutera, A., 1986: Probability density distribution of large-scale atmospheric flow. *Adv. Geophys.*, 29, 227–249.
- Tang, Maocang, and E.R. Reiter. 1984. Plateau Monsoons of the Northern Hemisphere: A Comparison between North America and Tibet. *Mon. Wea. Rev.*, 112, 617–637.
- Wallace, J.M., and D.S. Gutzler, 1981: Teleconnections in the geopotential height field during the northern hemisphere winter. *Mon. Wea. Rev.*, 109, 784–812.
- Wiedenmann, J.M., A.R. Lupo, I.I. Mokhov, and E. Tikhonova, 2002: The Climatology of Blocking Anticyclones for the Northern and Southern Hemisphere: Block Intensity as a Diagnostic. *Journal of Climate*, 15, 3459–3473.
- Yarnal, B., 1993: *Synoptic Climatology in Environmental Analysis*. CRC Press, Boca Raton Fla., 195 pp.

Comments on *Coenogonium missouriense* Davis, A Unique Microlichen From A Cave in Central Missouri

Joseph S. Davis

Department of Botany, University of Florida, Gainesville, FL 32611

Abstract: The common occurrence of cyanobacteria colonies attached to the exposed surfaces of the microlichen *Coenogonium missouriense* and the production of short filaments of cobblestone-shaped fungus cells at the apex of the association are documented. It is possible that the colonies contribute to the survival of the association in the cave environment, and that environmental conditions in the cave maintain the cobblestone shape of the fungus component of the microlichen.

Key Words: cave algae, lichens, microlichens, *Physolinum*, *Trentepohlia*

Introduction

While exploring several caverns in central Missouri during 1981–1982, the author discovered a unique microscopic lichen in Onyx Cave. After completing two studies concerned with morphology and ecology of the association (Davis et al. 1989, Davis and Rands 1993), I described *Coenogonium missouriense* (Davis 1994), a new species of the ascolichens. In its possession of a hyaline, highly characteristic fungal component (the mycobiont) to which cyanobacteria are attached, *C. missouriense* differs from the microscopic lichens with widely separated hyphae attached to the algal component (Henssen and Jahns 1974), and with the lichens covered by black hyphae (Koch 1982, Skuja and Ore 1933). The present paper reports on a cyanobacterial epiphyte of the microlichen from Onyx cave, and comments on the production of cobblestone-shaped mycobiont cells growing in a series at the apex of the association.

Onyx cave, a dolomite cavern on a cliff above the Gasconade River, is located in Pulaski County in the Ozark region of Missouri. In the 1980's the two mouths of the cave faced northwest and opened into a large entrance room approximately 30 m x 70 m with a ceiling height of 12 m. Photon fluence rates at the rear of the entrance room with the microlichen were 0.01 to $0.05 \mu\text{E} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$ at 2:00 PM on a bright day in June (Davis et al. 1989). An opening beyond the back wall of the cave permitted air to flow through the cave. Pastel green patches occurred on the side and back walls where light was able to reach. On the sidewalls the patches contained common species of free-living and lichenized terrestrial algae, but on the moist back wall the colored areas consisted largely of *Coenogonium missouriense*. The richly branched, pastel green filaments of *C. missouriense*

consisted of a uniseriate algal component (the photobiont) ensheathed by hyaline fungal cells (5 to 8 in a single layer) that adhered tightly to each other and completely covered the association (Fig. 1). The algal component of the lichen, *Physolinum monile* (*Physolinum* = *Trentepohlia* according to Thompson and Wujek 1997), is a terrestrial member of the filamentous green algae (Chlorophyta); the fungal component is a member of the filamentous ascomycetes. Cells of the mycobiont fit together tightly like cobblestones on a walkway, extended haustoria into the *Physolinum* cells, and contained concentric bodies. The lichen formed thin mats (1-2 mm) firmly adherent to the moist dolomite substratum (Fig. 2). Organisms among the *C. missouriense* filaments included *Nostoc* sp., *Melosira roeseana*, *Synechococcus* sp., *Hapalosiphon intricatus*, *Chroococcus turgidis*, bacteria, ciliates, and nematodes.

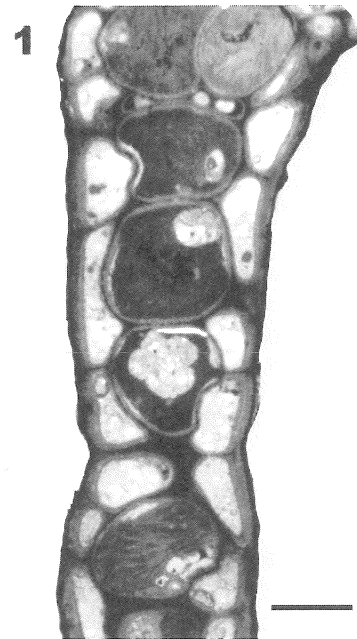


Figure 1. A section through *Coenogonium missouriense* showing the central algal filament and peripheral hyaline fungus cells. Bar = 15 μm .

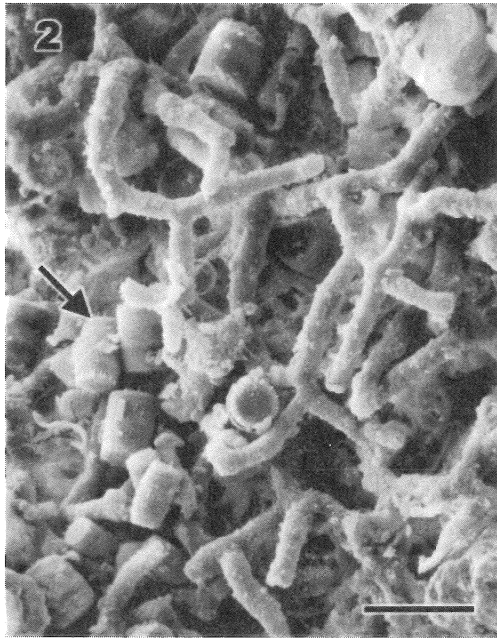


Figure 2. A mat of *C. missouriense* filaments from the back wall of the cave. The diatoms are *Melosira roeseana* (arrow). Bar = 10 μm .

Materials and Methods

During the 1980's the author and co-workers visited the cave and collected *Coenogonium missouriense* several times during all seasons. Although temperatures and humidities varied from season to season (Davis et al. 1989), no visible differences in the microlichen were ever observed during the visits. The observations below are from specimens preserved in 3.7% formaldehyde solution or 3% glutaraldehyde-paraformaldehyde, collected during the 1980's. Further methods for study and culturing of the microlichen are detailed in Davis et al. (1989).

Study of a large number of *C. missouriense* filaments revealed 1) common to abundant occurrence of cyanobacteria colonies attached to the exposed walls of the fungus component, and 2) cobblestone-shaped fungus cells that grew into short filaments beyond the apical cell of the photobiont. The attached colonies have been identified as *Synechocystis*-like by Davis and Rands (1993). The following comments are offered to supplement information previously published. Because the attached cyanobacteria may be important to the survival of the microscopic lichen in the harsh cave environment and because the mycobiont produces cobblestone-shaped cells in the cave but not in culture.

Results and Discussion

The cyanobacteria colonies of few to numerous cells adhered to the mycobiont at irregular intervals along the association. Cells of the colonies were embedded in a firm transparent matrix which in part contacted the exposed walls of the fungus component. Most colonies adhered to one to three cells of the fungus (Davis et al. 1989), the colonies occasionally covered about half the diameter of the association (Fig. 3). Fungal cells in contact with colonies often were slightly larger than most ensheathing fungal cells of the microlichen.

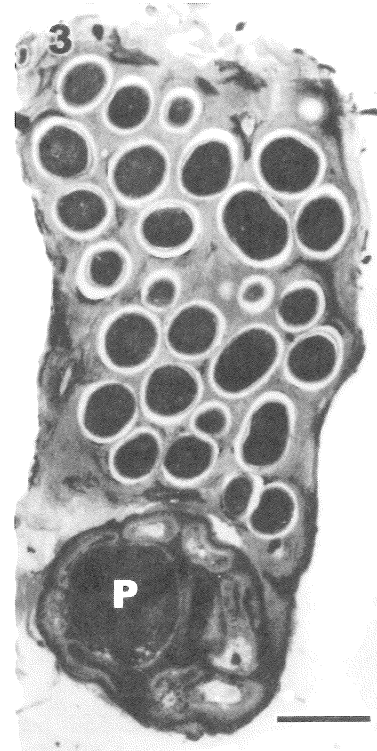


Figure 3. A *Synechocystis*-like colony attached to a *C. missouriense* filament. P = photobiont. Bar = 5 μm .

In specimens preserved directly after collection, fungus cells often extended beyond the apical photobiont of the association (Fig. 4) to form a short series of cells. The shape of these fungal cells was similar to the cobblestone-like cells surrounding the *Physolinum* algal component. Cyanobacterial colonies also were attached to the cobblestone-like fungal cells that extended beyond the apical photobiont. Because of their distance from the photobiont, such fungal cells would seem to obtain part of their organic nutrients from the attached cyanobacterial colonies. The somewhat eroded cell wall of a mycobiont below and attached cyanobacterial colony (Fig. 2, Davis et al. 1989) may indicate a possible pathway of nutrients to the fungus component.

In contrast to the cobblestone shape of the fungus component in the association, the ensheathing cells of *Coenogonium missouriense* developed cylindrical hyphae after the lichen was cultured with organic nutrients. However, no cylindrical hyphae were ever found in free-living specimens of the lichen.

Lichen genera with green algae as their primary photobiont and cyanobacteria as their secondary one are well known. These cyanobacteria, called cephalodia when contained in gall-like structures, consist of species capable of nitrogen fixation (Friedl and Büdel 1996). It seems reasonable to assume that the cyanobacteria attached to *Coenogonium missouriense* are secondary photobionts and that they contribute to the nitrogen economy of the association. It is also possible that the cyanobacteria on *C. missouriense* are a primitive expression of cephalodia.

In August 1990, accommodations for commercial tourism in the cave were completed and resulted in higher light levels and decreased air flows through the cave. During several visits in the 1990's to Onyx Cave, I was unable to find *C. missouriense*. The

author hopes the above comments will promote further research on *C. missouriense* and encourage increased exploration of cave microorganisms in Missouri. Preserved specimens can be obtained by contacting the author.

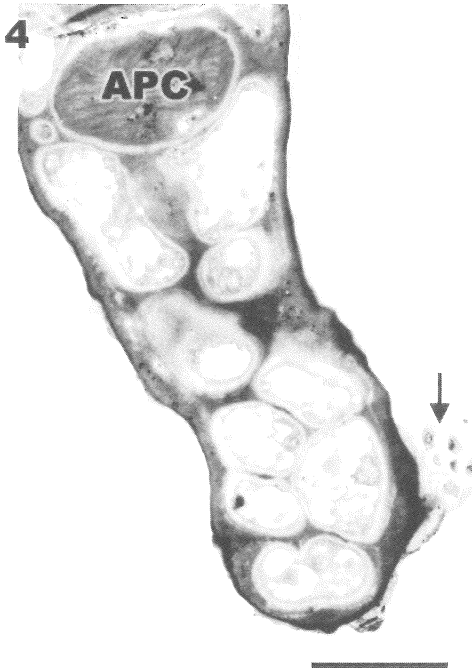


Fig. 4. A series of cobblestone-shaped fungus cells that extend beyond the apical photobiont cell (APC). A *Synechocystis*-like colony is attached at lower right (arrow). Bar = 40 μ m.

Literature Cited

- Davis, J. S., Rands, D. G., and Lachapelle, M. 1989. Heavily lichenized *Physolinum* from a dimly lit cave in Missouri. *J. Phycology* 25:419-428.
- Davis, J. S. and Rands, D. G. 1993. Observations on lichenized and free-living *Physolinum* (Chlorophyta, Trentepohliaceae). *J. Phycology* 29:819-825.
- Davis, Joseph S. 1994. *Coenogonium missouriense*, a new lichen species from Missouri. *The Bryologist* 97:186-189.
- Friedl, T. and Büdel, B. 1996. Photobionts. In: Nash, T. H. (ed.), *Lichen Biology*. Cambridge University Press, 8-23.
- Henssen, A. and Jahns, H. M. 1974. *Lichenes. Eine Einführung in die Flechtenkunde mit einem Beitrag von Johan Santesson*. Georg Thieme Verlag, Stuttgart, 467 pp.
- Koch, W. 1982. Die Gonidie von *Racodium rupestre* Pers. *Fort. Gesamtgeb. Bot. Dtsch. Bot. Ges. N.F.* 1:61-64.
- Skuja, H. and Ore, M. 1933. Die Flechte *Coenogonium nigrum* (Huds.) Zahlbr. und ihre Gonidie. *Acta Hort. Bot. Univ. Latviens.* 7:21-55.
- Thompson, R. H. and Wujek, D. E. 1997. *Trentepohliales: Cephaluros, Phycopeltis, and Somatochroon; morphology, taxonomy, and ecology*. Science Publishers, Enfield, New Hampshire.

Senior Division

2002

Agriculture Section

Chairs: Michael Aide and Mack Wilson

***Aide, M.T. and Z. Pavich. Department of Geosciences, Southeast Missouri State University.** SPODIC HORIZON DEVELOPMENT IN WISCONSIN SPODOSOLS. Spodosols are soils commonly located in the northern Great Lake States and having a spodic horizon. Spodic horizons are depicted as having an accumulation of Al, supposedly formed by downward leaching organic complexes. The purpose of this study was to determine if elements other than Al and Fe are chelated by soil organic matter and illuviated to deeper soil horizons. We present evidence that the rare earth elements are slightly concentrated in the spodic horizon and that these elements are concentrated by the same soil processes responsible for Al migration.

Madzura, T. University of Missouri Outreach and Extension, Columbia. INTERNET INFORMATION- A TOOL FOR WATERSHED MANAGEMENT. There is a critical need for information on the relative designs, plans, implementation and evaluation measures used to restore or rehabilitate water pollution sources. Working together with University Extension personnel, state, federal and non-governmental agencies, the Missouri Watershed Information Network (MoWIN) will plan and implement regional training workshops in Missouri. Workshops will include ways to find key elements for developing watershed restoration action strategies, source water protection plans, total maximum daily loads and water quality management plans. Target audiences will include landowners, land managers, locally led watershed alliances, decision and policy makers, educators, researchers, or volunteers. Pre-surveys will be conducted to determine the extent of watershed activities and/or education and information requirements. Using a watershed approach to restore the environment fosters a coordinated and efficient implementation effort of programs that reduce polluted runoff, protect natural resources and drinking water supplies. Providing information at a watershed level increases citizen accountability and involvement, as well as promotes a holistic way of managing watersheds. This project is an additional empowerment resource for Missourians to make informed watershed management decisions. The project will contribute to watershed restoration activities by promoting awareness of watershed-related information and educate citizens on how to access the various categories of information. Hands-on activities will be provided to train participants to utilize existing information and data. For additional information please visit: <http://www.outreach.missouri.edu/mowin>

Strong, C.D., F.D. Worman and L.A. Watkins. Department of Agriculture, Central Missouri State University. FACTORS AFFECTING THE BEEF CONSUMPTION OF COLLEGE STUDENTS AT CENTRAL MISSOURI STATE UNIVERSITY. This project was conducted to find out what factors influenced the consumption of beef products among college students. A survey was administered to 135 students enrolled in a general studies education class, Global Agriculture, during the Fall 2001 semester. The survey contained questions regarding student's demographic characteristics, current college characteristics, consumption patterns relating to beef and shopping habits of students. A general description of statistical analysis and chi-square analysis were used to determine significant relationships among the variables. It was found that age and gender of a college student had an affect on the consumption of beef among college students. Even though students were aware of health issues associated with eating beef, they did not let these concerns affect their consumption of beef products. Students were also looking for convenience in beef products to fit their college lifestyle. Whether a student was from a rural or urban area and income did not affect the consumption of beef products among students attending college.

***Wilson, M.A., D. Harp, C. Stevens, and V. Khan. Southeast Missouri State University and George Washington Carver Experiment Station, Tuskegee University.** INFLUENCE OF NUTRIPAK FERTILIZER ON YIELD OF POTATOES. The experiment was conducted in a split-split plot design in 2001 to determine the effect of NutriPak on yield of potatoes. Potatoes were emerged from soil by April 10, 2001. Potatoes were sprayed with 3 applications of NutriPak of 8, 16 and 32 oz. per acre at 3 different growth stages; 3 to 4 in high, pre-flowering and at flowering. Total number of grade A potatoes was not significant for regression analysis of four dose levels of NutriPak fertilizer on "Atlantic" potatoes with bare soil treatment. But, the data showed that potato numbers were highest with the 16 oz. of NutriPak per acre with bare soil treatment. Potato yields were consistently higher for both grade A and grade B with NutriPak fertilizer at 16 oz. per acre.

Winkeler, E.L., R.D. Aldridge and A.P. Bufalino. Department of Biology, Saint Louis University. HISTOLOGY OF THE OVIDUCT OF MODERN SNAKES, PRIMITIVE SNAKES, AND THE WORM LIZARDS. The oviduct is part of the reproductive system that does not change rapidly over evolutionary time. All modern snakes, whether they are egg laying (oviparous) or live bearing (ovoviviparous), have the same basic oviductal anatomy. Similarly, as a group, lizards also have similar anatomy which may make this structure useful in determining phylogenetic relationships among major groups of reptiles. In this study we will examine the histological anatomy of the oviducts of the brown house snake (*Lamprophis fuliginosus*), the Brahminy blind snake (*Rhamphotyphlops braminus*), and the

worm lizard, *Amphisbaena fuliginosa*, to determine if the anatomy of the worm lizard oviduct is more similar to the snakes or lizards. The oviduct will be cut into sections, and placed into cassettes for dehydration, clearing in toluene, and infiltration with wax. When cooled the blocks of tissue will be cut at 7 μm , placed on glass slides, and stained with hematoxylin, fast green, orange II and Biebrich scarlet.

Atmospheric Sciences

Chair: Anthony R. Lupo

Ebert, R.L., and P.S. Market. Department of Atmospheric Science, University of Missouri-Columbia. ASPECTS OF THUNDERSNOW EVENTS IN MISSOURI. Thirteen (13) individual events of thundersnow were identified over Missouri for the period 1961-1990. Surface observations from St. Louis, Kansas City, Springfield, and Columbia, Missouri, were used to further identify events that featured thunder with snow only (11). The sparse spatial data coverage and limitations with the dataset preclude the compilation of a regional climatology. However, of the ten (10) events with sufficient upper air data identified over Missouri, more than half (7) featured moderate or heavy snowfall, and four (4) of those featured heavy snowfall at some point during the event. The synoptic setting of these events falls into two categories: 1) the presence of a transient cyclone (8 of 10), and 2) isentropic upglide over an arctic frontal boundary (usually as return flow west of an anticyclone; 2 of 10). In addition, 7 of the 10 cases occurred in southerly or southwesterly flow aloft (500 mb), 2 featured west or northwest flow, and one was indeterminate.

Lam, J.E., P.S. Market, and A.R. Lupo. Department of Atmospheric Science, University of Missouri-Columbia. THE AFFECT OF AN URBAN HEAT ISLAND ON DOWNWIND LOCATIONS. This work constitutes a further investigation of the Columbia Heat Island Experiment (COHIX) data first presented last year. With this study, we will show that the affects of an urban heat island can be transported downwind. Data were examined from October 2000 to May 2001. Of the 243 days in the period, 95 did not involve a wind shift or precipitation at some point during the day. On these 95 days, a dominant wind direction was determined (northeast, southeast, southwest, and northwest) as was the quadrant of the city that experienced the highest temperature that day. The quadrant from which the wind was blowing and the quadrant of the highest maximum temperature were correlated (-0.267) at a 99% confidence interval. This indicates that the heat from the urban area was being transported downwind by the prevailing flow. The data were stratified by clear/cloudy sky conditions as well as by wind/not-windy days. Of greatest interest is the complete lack of evidence of thermal advection on days with winds in excess of 10 knots, indicating the affects of mixing. Days with winds less than 10 knots have a correlation between the quadrant from which the wind was blowing and the quadrant of the highest maximum temperature of -0.360 valid on the 99% confidence interval.

Lupo, A.R., E. McCoy, S. Allen, A. Akyuz, E.P. Kelsey, C. Halcomb, E. Aldrich, D. Beiger, E. Wise, M. Edwards, and D. Schmidt. Department of Atmospheric Sciences, University of Missouri-Columbia. THE PRESENTATION OF TEMPERATURE INFORMATION IN TELEVISION BROADCASTS: WHAT IS NORMAL? In a typical weather broadcast, observed daily temperature information such as maximum and minimum temperatures are shown and compared to normal. Such information, however, does not accurately describe whether or not that particular day is fairly typical for that time of year or truly an unusual occurrence. Thus it is suggested that the presentation of temperature information can be augmented with elementary statistical information in order to give a more meaningful presentation of weather information without the need to explain the basis of such statistical information. A study of the climatological maximum and minimum temperatures over a 30-year period for Columbia, Missouri is performed in order to provide the rationale for displaying a "typical" temperature range along with daily observations. This information was incorporated into television weather broadcasts at KOMU TV-8, the campus television station and local NBC affiliate.

Lupo, A.R., D. Albert, R. Hearst, C. L. Allmeyer, and P.S. Market. Department of Atmospheric Sciences, University of Missouri-Columbia. INTERANNUAL VARIABILITY OF SNOWFALL-TO-LIQUID WATER AMOUNTS IN SOUTHWEST MISSOURI. Forecasting the snowfall amounts for an approaching synoptic system is one of the most formidable challenges for weather forecasters. By using data acquired from the Missouri Climate Center and the National Weather Service Forecast Office in Springfield, Missouri, a climatology of snowfall-to-liquid (LS) ratios was derived for Southwest Missouri. A climatology of Southwest Missouri snowfalls was derived and then compared to a climatology using observations from the Springfield Weather Service Office only. These climatologies were very similar overall. Thus, LS ratio data, which is only available to Springfield, Missouri observations alone, should adequately represent LS ratios for Southwest Missouri. It was found that winter snowfalls had a higher LS ratio than those in the fall or spring season. Overall, most snowfall events had an LS ratio of less than 12 inches of snow to 1 inch of liquid (12:1). Higher LS ratios were associated with northwest flow regime snow events, while lower ratios were found with southwest flow regime events. When examining the interannual variability, the percentage of low LS ratio snowfall events in El Nino years was significantly higher. This mirrored the greater frequency of southwest flow regime snowfall events in these years.

Market, P.S., and M. Bodner. Department of Atmospheric Science, University of Missouri-Columbia. NOAA/Hydrometeorological Prediction Center, Camp Springs, Maryland. THE CHICAGO-DUPAGE, ILLINOIS, THUNDERSNOW EVENT OF 31 JANUARY 2002. A case study is presented of a thundersnow event not associated with a strong cyclone, and well north of a surface quasi-stationary frontal boundary. Standard analyses reveal the presence of an 850 mb frontal zone, broad southwesterly flow at 500 mb, and the right entrance region of an anticyclonically curved jet streak at 250 mb all over the region at the time of the event. Initial fields

from the Rapid Update Cycle (RUC) model at the time indicate the presence of ample moisture and strong frontogenesis in the presence of weak conditional symmetric instability over the region. A small area of conditional symmetric instability was diagnosed at ~850 mb just south of the thundersnow event location. Aircraft soundings from the time of the event suggest little in the way of instability over northern Illinois, and the lightning detection network failed to detect cloud-to-ground lightning strokes there. Still, lightning and thunder were observed with the event at DuPage, Illinois, suggesting the presence of vertical motions strong enough to generate charge separation.

Podrazik, K., and P.S. Market. Department of Atmospheric Science, University of Missouri-Columbia. STATISTICAL MODEL PERFORMANCE IN FORECASTING AVIATION-SENSITIVE WEATHER VARIABLES. The Aviation Model's model output statistics (AVN MOS) guidance were collected for the period of September 2000-August 2001. These output were compared to actual surface observations from the Columbia Regional Airport (COU). In particular, variables germane to aviation operations (cloud cover, ceiling, and visibility) were examined. Days without cloud cover or low ceilings, and those with high visibilities were excluded from the study. Skill was assessed for multiple model runs valid at the same time. Not surprisingly, the forecast skill of AVN MOS for these variables improves as the lead-time before a forecast hour dwindles.

Podzimek, J. and M. Podzimek. Cloud and Aerosol Sciences Laboratory, University of Missouri-Rolla. NEW DIVISION AND PARAMETERIZATION OF SNOWFLAKES. A new division of snowflakes is suggested based on the analysis of snow crystal and snowflake samples collected over eight years in the Midwestern United States. The division is rooted in the prevailing presence of specific snow crystals in aggregates and contains the following six types of aggregated snowfall elements: Needles and sheaths; small columnar and plate crystals; medium size plate and stellar crystals; large dendritic and stellar crystals; aggregates of minigraupels and frozen drops; mixtures of large drops (often from melted snowflakes) and snow crystals. Calculations performed for each group of snowflakes include the mean occurrence during long-term sampling and the mean morphological and dimensional parameters. The morphological parameters consist of the mean crystal number in a snowflake, the types of aggregated crystals, and the potential interaction of rimed crystals. The mean size and maximum size of the specific type of snowflake are among the dimensional parameters mentioned. The size distribution curves of the five first groups of snowflakes are also carefully considered. A simple log-normal distribution is suitable for only one or two groups of snowflakes (e.g. for large dendritic aggregates). Attention was also paid to the simultaneous occurrence and interaction of different types of snowflakes at specific meteorological situations.

Podzimek, J. and E. Robb. Cloud and Aerosol Sciences Laboratory, University of Missouri-Rolla. SNOW CRYSTAL FRAGMENTS COLLECTED AT THE GROUND. The evaluation of 885 snow crystal replica samples collected at Rolla, MO, and at Groveland, IL, during the years 1993-2001 document the importance of the snow elements for the modeling of a self-

cleaning atmosphere, the study of visibility, and other phenomena in the atmospheric boundary layer. More than 63% of snow crystal samples--each usually comprised of more than 100 crystals-- contained broken arms of dendritic and stellar crystals. These fragments were divided into one arm, two arm, and three arm elements classified as either dendritic or stellar. For each element, the main dimensional and morphological parameters affecting the motion and aggregation of falling crystals were established. The mean sizes of dendritic one arm fragments were 1.16 mm, of two arm fragments 1.21 mm, and of three arm fragments 1.49 mm. The corresponding fragments of stellar crystals were 0.80 mm, 0.89 mm, and 1.02 mm. Possible effects of the air temperature, wind speed, riming, and presence of frozen droplets or minigraupels on the crystal fragmentation were investigated. It appears that the temperature and wind speed at the ground does not substantially affect the occurrence of fragments, which is usually related to the formation of very large dendritic and stellar crystals at temperatures around -15°C in the atmosphere.

Rutter, A. P.,¹ P.D. Whitefield,¹ D.E. Hagen,¹ A.R. Hopkins,¹ and M. Ross.² ¹Cloud and Aerosol Sciences Laboratory, University of Missouri-Rolla. ²Air Force Office of Scientific Research. OBSERVATIONS OF VOLATILE AND NON-VOLATILE PARTICULATES IN A HIGH ALTITUDE ROCKET PLUME. Measurements of Non-volatile and volatile (~198°C) particulates were made at high altitude (16-19km) in the exhaust plume of the Athena II (IKONOS, 9/24/99, Vandenberg Air Force Base) rocket. Size distributions and particulate concentration profiles of total and non-volatile particulates extending over the size range of 8-4000nm were measured. Data in the size range 340-4000nm was collected throughout the flight using laser particle counting techniques. Data in the size range 8-250nm were acquired only during plume incursions using a Grab Tank Sampling system. The NASA WB-57F high altitude research aircraft was used as the experimental platform. Three modes were observed in the particulate size distributions centred at <8nm, 50-60nm and 900-1000nm. The relative mass fractions present in each mode were 0.04%±0.03, 7.39%±3.96, 92.57%±4.00. A volatile component was observed for the first time in the Athena II measurement flight. References: [1] Ross, M.N., P.D. Whitefield, D.E. Hagen and R. Hopkins, "In-Situ Measurement of the Aerosol Size Distribution in Stratospheric Solid Rocket Motor Exhaust Plumes", Geophys. Res. Let. 26, 819-822. (1999).

Zacher, C.A. and J.T. Moore. AERO Research and Department of Earth and Atmospheric Sciences, St. Louis University. REVISITING BIPOLAR PATTERNS IDENTIFIED IN TRACKING ELECTRIFIED MESOSCALE CONVECTIVE SYSTEMS. We have called attention in an earlier paper on the synoptic development of cloud-to-ground (CG) lightning discharges tracked across the country, to the relative positional placements of positive (+) and negative (-) flashes within storms (MAS Transaction, 1991). Mapping shown on-screen is produced in near real time by an updated National Lightning Detection Network (NLDN) array of sensors and ultimately communicated via satellite link through the Lightning Data and Information Systems (LDIS). This information transmitted, especially in developing mesoscale convective systems

(MCS), a predominance of positive CG flashes appearing in advance of negative CG flashes, contrary to expectations. This would reverse (seemingly) the order of precedence – convective elements with negative discharges initially, leading to stratiform, anvil-like portions with positive discharges subsequently. We will hereby reexamine some factors that might contaminate these data, falling broadly in two areas: 1) Confusion with, or synchronous intracloud flashes, and 2) Instrument detection limitations. The conclusion is that we strongly suspect masking or data contamination by such factors.

Biology Section

Aldridge, R.D., A.P. Bufalino, and P. Khayyat. Department of Biology, Saint Louis University. **THE CONFLICT BETWEEN COURTSHIP AND FEEDING IN THE COMMON WATERSNAKE (*NERODIA SIPEDON SIPEDON*).** During the breeding season, female snakes release sex pheromones to advertise their reproductive condition to males. Females must be attractive for a long enough period of time to successfully mate, however continued attractiveness may result in unwanted courtship. Such unwanted courtship might interfere with critical aspects of the female's ecology, such as foraging and feeding, which may ultimately reduce her reproductive success and thus her fitness. We describe an observation of a female *Nerodia sipedon sipedon* attempting to feed on a large male *Rana catesbeiana* while being courted by two males. This observation was near the end of *N. s. sipedon*'s breeding season in the Missouri Ozarks and the female was unreceptive to the male's courting attempts. During the observation period, the female unsuccessfully tried to terminate the encounter by escaping from the males while maintaining her grasp on the *R. catesbeiana*. The female was never observed to lose her grasp on the *R. catesbeiana*, though the unwanted attention from the males clearly disrupted her feeding attempt.

Carrel, J. E. Division of Biological Sciences, University of Missouri-Columbia. **RESPONSE OF BURROWING WOLF SPIDERS (LYCOSIDAE: *GEOLYCOSA* SPP.) TO FIRE IN FLORIDA SCRUB.** On February 12, 2001, I began a "natural experiment" made possible by an intense wildfire that quickly incinerated 250 ha of drought-stricken scrub at the Archbold Biological Station in south-central Florida. First, I determined that most (83%) burrowing wolf spiders (*Geolycosa* spp.) survived the blaze by remaining deep underground in their burrows. Mortality was confined to small spiders, which are known to have shallow (< 5 cm deep) burrows. Second, populations of *Geolycosa* spp. in burned scrub increased dramatically by the end of the year, much as I had documented a decade earlier after another wildfire destroyed the vegetation and exposed the sandy soil. Third, replicate measurements made at 0.5, 4, 8, and 12 months post-burn suggested that the increase in *Geolycosa* densities in burned scrub relative to unburned scrub was attributed to abiotic factors, such as increased availability of burrow sites and increased soil temperatures that hastened growth and date of first reproduction, rather than biotic factors, such as more or higher quality prey for spiders foraging at the soil surface.

Higgins, P.M., and Burt, M.S. Department of Biology, Truman State University. **SMALL MAMMAL COMMUNITY RESPONSES TO OAK-SAVANNAH RESTORATION.** Small mammal communities have largely been ignored as possible indicators to gauge the success or progress of ecological restorations. Current management programs at Thousand Hills State Park (THSP) near Kirksville, Missouri provide the opportunity to assess the effects that prescribed burns can have upon small mammal communities, and the degree to which the communities change over time. For example, relative numbers of *Microtus ochrogaster*, a species typical of the prairie, could be a useful indicator for the relative success of burns designed to restore habitat from forest to grassland. Also, by including data from previous work that was done at the same location in 1995, we can track changes in communities over the course of the restoration program. Results from this project will be used to gauge the success of the burn management techniques as well as to monitor and interpret any fluctuations that have occurred in community composition. Specifically, we will compare communities of small mammals in two habitats from both 1995 and today. We have constructed web-trap arrays in the burned areas and the undisturbed forested habitats. Mammals are live captured, appropriate data collected, and the animals marked before being released at the capture site. Data collection for this project began in September of 2001 and will continue at least until September of 2002. To date, we have 3,024 trap nights, and from these data have preliminary estimates of community diversity and abundance values. We would like to thank the Missouri Department of Conservation for providing the funds necessary to conduct this field study.

Keller, H.W., K.L. Snell, M. Skrabal, D. Lesmeister, J. Counts, and L. Henley. Department of Biology, Central Missouri State University. **STUDENT CLIMBING AND COLLECTING EXPERIENCES IN THE GREAT SMOKY MOUNTAINS NATIONAL PARK.** This research project involved undergraduate, graduate students, volunteers, park interns and a multidisciplinary team of experts in the collection and identification of Myxomycetes, macrofungi, lichens, mosses, liverworts, ferns, tardigrades, and molluscs from the tree canopy. Students compiled a field diary of their experiences included in park interpretive exhibitions, news media coverage (print and television) and publications such as THE INOCULUM, THE MYCOPHILE and the INTERNATIONAL CANOPY NETWORK. A video tape entitled "A Study with a View" aired as part of a television story for the "Heartland Series" produced by WBIR Channel 10 in Knoxville, Tennessee. Bill Landry has been the host/narrator since the Heartland Series was conceived in 1984 to commemorate the 50th anniversary of the founding of the Great Smoky Mountains National Park. This program celebrates the people and the land of the entire Appalachian region. The television crew spent two days shooting the climbing and sampling techniques in the Cades Cove area of the park. Many of the panoramic views were shot from a cherry picker with the cameraman in the bucket at a height of 70 to 80 feet. The double rope climbing technique will be described beginning with climbing school and certification by a professional arborist to accessing the tree canopy of champion-sized trees. This research project is funded by the National Science Foundation, Division of

Environmental Biology, Biotic Surveys and Inventories Program, Award #DEB-0079058 and Discover Life in America Award #2001-26.

Keller, H.W. and K.L. Snell. Department of Biology, Central Missouri State University. LIFE IN TREETOPS IN THE GREAT SMOKY MOUNTAINS NATIONAL PARK. The Great Smoky Mountains National Park (GSMNP) has over 40,000 hectares of old-growth forest in the Tennessee-North Carolina region of eastern United States. The All Taxa Biodiversity Inventory (ATBI) program will attempt to complete a comprehensive inventory of all life forms in the Park. This research study will include the first comprehensive inventory of cryptogams (myxomycetes, macrofungi, mosses, liverworts, lichens, and ferns) and also tardigrades and molluscs in the tree canopy. A student research team climbed a total of 240 trees representing 35 different tree species during two three-week periods in June, July and August of calendar years 2000 and 2001. Using the double rope climbing technique students scaled the tree canopy to heights of 40 meters. The total number (107) of myxomycete species recorded from the tree canopy included 52 new records for the GSMNP. A new species of *Diachea* was restricted to heights above 6 meters. This is the first upper tree canopy species documented for the Myxomycetes. Apparently the Myxomycetes are the only group of cryptogams with obligate tree canopy species. This research project is funded by the National Science Foundation, Division of Environmental Biology, Biotic Surveys and Inventories Program, Award # DEB-0079058 and Discover Life in America Award #2001-26.

McClain, W.E. and F.A. Einhellig. Departments of Agriculture and Biology. THE COMBINATION OF LIGHT AND ALLELOPATHIC EFFECTS ON SOYEAN SEEDLINGS. This research focused on determining how variations in light level in conjunction with a known allelochemical stress affected growth and photosynthesis. Using a completely randomized split-plot design we observed the effects of ferulic acid (FA) and light on plant biomass, photosynthetic capacity, and stomatal conductance. Light regime was the main effect (ambient conditions and $\approx 40\%$ reduction by shade cloth) and the subplot was defined by FA (0 μM , 250 μM , and 500 μM). Soybean seedlings were grown in nutrient culture under glasshouse conditions of the summer season. Treatments began 10 days after germination and plants were harvested on day 40. General linear model (GLM) analysis of harvest dry weights showed highly significant FA, light, and interaction effects. Periodically during the month of treatment, light response curves were taken with a LiCor 6400 Photosynthesis system. Ferulic acid caused a concentration-dependent reduction in photosynthetic rate in the range of light saturation, albeit this reduction in photosynthesis was of less magnitude near the end of the experiment. Sun-grown plants had greater overall photosynthetic capacity at high light levels, regardless of FA concentration. Several interactive effects appear to occur between FA and light intensity, the most prominent being that shade-grown plants had greater FA effects at high light throughout the experiment. The strong correlation between conductance and photosynthetic rate indicates that reductions in the latter are primarily due to stomatal limitations. This stomatal limitation is most likely the pri-

mary action of both sun and FA. While FA effects were modified by light conditions, it appears that alterations in photosynthesis were only part of the explanation for plant growth reductions observed in this experiment.

Moffatt, D.S., K. Manivannan, and L.E. Banks. Center for Scientific Research and Education, Southwest Missouri State University. CELL MEMBRANE SODIUM/POTASSIUM PUMP: COMPUTER MODELING WITH STELLA. Cell membranes have a sodium/potassium pump that moves sodium (Na^+) out and potassium (K^+) into the cell. This pump is reported to have an influence on cell volume. We have investigated various aspects of the pump using the computer simulation software STELLA. This software makes it easy for students to explore quantitative concepts without any formal knowledge of calculus. The simulations involved three linked differential equations of cell volume, concentrations of Na^+ and K^+ in the cell. Analysis of the model revealed several interesting dynamics of the system including: (1) Extrusion of Na^+ from the cell keeps the cell from overhydration. (2) Moving K^+ into the cell increases cellular volume. (3) Control of cell volume is highly sensitive to the amount of K^+ pumped into the cell. Our findings indicate that a feedback loop involving the Na^+/K^+ pump is necessary to maintain constant cell volume. In addition, our experience with STELLA proves it to be a valuable tool in research as well as in education. This work was supported in part by the United States Department of Education grant# P342A990411.

Raveill, J. A. Department of Biology, Central Missouri State University. THE TRIBE DESMODIEAE (FABACEAE) IN MISSOURI. The tribe Desmodieae (Fabaceae) is reexamined in preparation for a treatment for volume two of Steyermark's Flora of Missouri. The treatment covers 20 species of *Desmodium* (plus one named hybrid), 11 species of *Lespedeza*, and two species of *Kummerowia*. All species are native except for the two *Kummerowia* species and three species in *Lespedeza*. Relevant collections from major herbaria were examined and literature reviewed for its impact on this tribe in Missouri. The most significant departure from traditional nomenclature is the recognition of two introduced annual species formally treated in *Lespedeza* as belonging to a segregate genus, *Kummerowia*. The recent segregation of the genus *Hylodesmum* from *Desmodium* is rejected. The transfer would involve three largely woodland species, *D. glutinosum*, *D. nudiflorum*, and *D. pauciflorum*, as well as 11 Asian species. One *Desmodium* is now recognized as a hybrid, *D. ¥ humifusum* ($=D. paniculatum ¥ D. rotundifolium$) and one new and presumably native species has been added to the flora, *D. strictum*. An introduced shrubby species of *Lespedeza*, *L. bicolor*, is added to the flora. Reexamination of type material has required that the name *L. violacea* replace *L. intermedia* and that *L. frutescence* be used for those specimens formerly called *L. violacea*. Funding provided by the Missouri Department of Conservation.

Robison, C.R., A.P. Bufalino, and R.D. Aldridge. Department of Biology, Saint Louis University. A PRELIMINARY ANALYSIS OF PRE-COURTSHIP ASSESSMENT BEHAVIORS IN MALE BROWN HOUSE SNAKES (*Lamprophis fuliginosus*). Two major components of snake reproduction are the attractiveness and receptiveness aspects of mating. Snake reproductive behavioral research has primarily focused on courtship behaviors, which addresses a male's attempt at determining a female's receptiveness to mating. Prior to initiating courtship behavior, a male must determine if a female is attractive, which she communicates through the release of sex pheromones. We analyzed the pre-courtship period of male/experimental (attractive female) and male/control (male, unattractive female, or rubber snake) pairings of *Lamprophis fuliginosus* to determine if males exhibit unique behavioral patterns while assessing the various treatments. Experimental trials were conducted in a 40-liter glass aquarium. Male test subjects had a 20-min. acclimation and experimental treatment period. Trials were video taped with a digital camcorder. Our analyses indicate that males show varying degrees of complexity in assessment behaviors based on the nature of the treatment. Males showed the least complex assessment behavioral pattern towards attractive females, and the most complex behavioral pattern towards unattractive females.

Uzzle, J.M., A.P. Bufalino, and R.D. Aldridge. Department of Biology, Saint Louis University. BODY MASS COMPARISON BETWEEN EGG LAYING AND NON-EGG LAYING BROWN HOUSE SNAKES (*LAMPROPHIS ULIGINOSUS*). In oviparous species, a female's activities are focused on gaining enough body mass to produce a clutch of eggs. We compared the pre and post-clutch body mass of egg laying females to the body mass of non-egg laying females. Egg laying females have mated with a male, whereas non-egg laying females are unmated. The focus of this study is a breeding colony of *Lamprophis fuliginosus*, an oviparous snake native to Africa, consisting of 17 males and 22 females. The colony is separated by sex and maintained at 22°C with a 12L:12D photoperiod. Results of our analysis, after controlling for body size, indicate a significant difference in body mass among the groups. Post-clutch body mass of egg laying females is significantly less than their pre-clutch body mass and the body mass of non-egg laying females. No significant difference was seen between the pre-clutch body mass of egg laying females and the body mass of non-egg laying females. These results indicate that a significant amount of a female's body mass goes into producing eggs and that unmated females tend to gain body mass above the average body mass of mated females.

Vowels, Christopher L. and Steve Mills. Department of Biology and Earth Science, Central Missouri State University. THE EFFECTS OF ENVIRONMENTAL STRESSORS ON LABORATORY RATS. The impact of changes in ambient temperature and light cycle had on body temperature, activity, and food/water consumption was examined using laboratory rats. In the first temperature experiment, to assess the effects of temperature decrease we acclimated rats at 70°F for five days, then decreased the temperature 10° F for five days and

then re-exposed the rats to 70°F for a final five days. The same five-day increment design was used in the second temperature experiment, but with a decrease of 15° F for the middle five-day period. An independent samples t-test showed that there was a significant difference in food consumption between experimental and control groups in the second temperature experiment when the temperature was decreased, $t(8) = -4.69$, $p < .01$. This showed that 15°F but not 10°F elicited a change in metabolic activity. There were no significant differences in body temperature or activity in either temperature experiment. In the light cycle experiment, we housed rats at around 70° F and at a normal light cycle period (off at 7 p.m./on at 7 a.m.) for seven days and then reversed the cycle for seven days (on at 7 p.m./off at 7 a.m.). There were no significant differences in food/water consumption, between experimental and control groups in the light cycle experiment. There were no significant differences in body temperature or activity in the light cycle experiment.

Winkeler, E.L., R.D. Aldridge, and A.P. Bufalino. Department of Biology, Saint Louis University. HISTOLOGY OF THE OVIDUCT OF MODERN SNAKES AND PRIMITIVE SNAKES. The oviduct is part of the reproductive system that appears to be conserved over evolutionary time. All modern snakes, whether egg laying or live bearing, have the same basic oviductal anatomy. Similarly, as a group, lizards also have similar anatomy which may make this structure useful in determining phylogenetic relationships among major groups of reptiles. In this study we examined the histology of the oviducts of the brown house snake (*Lamprophis fuliginosus*) and Brahminy blind snake (*Rhamphotyphlops braminus*) to determine if the anatomy of the blind oviduct is more similar to snakes or lizards. The oviducts were embedded in wax, cut at 7 µm, and stained with hematoxylin, fast green, orange II and Biebrich scarlet. The oviduct of both species were very similar and were made up of four distinct areas; the infundibulum, glandular portion, furrowed, and vagina. The blind snake oviductal anatomy was more similar to modern snakes than to the lizards.

Biomedical/Biotechnology Section

Chairs Albert R. Gordon and Colette M. Witkowski

***Chandler, LX, Witkowski, C. Biomedical Sciences Department, Southwest Missouri State University.** ANALYSIS OF A PUTATIVE CELL BINDING SITE IN THE $\alpha 2(IV)$ CHAIN OF *C. ELEGANS* COLLAGEN TYPE IV. The objective of this study is to analyze a possible cell binding site (CBS) composed of two aspartate residues and an arginine residue in the $\alpha 1(IV)$ and $\alpha 2(IV)$ chains of collagen type IV, respectively. In humans, an important CBS on the collagen type IV molecule has been characterized and it is located in the Gly-X-Y triple-helical domain. In *C. elegans*, the same residues are present only once, located relatively in the same position within the triple-helical domain. This conserved area is hypothesized to play an important role in the recognition of collagen type IV by cell-surface receptors. Research methods include generating strains containing extra-chromosomal arrays. The *let-2* gene encodes the $\alpha 2(IV)$ chain of collagen type IV. The *let-2* allele, *mm153*, causes abnor-

mal collagen type IV assembly and no secretion, resulting in collapse of muscle cells, and lethality. This mutant strain will be injected with plasmid constructs containing either the wild type *let-2* gene or a mutated copy (arginine to lysine substitution at amino acid 476). The marker gene *rol-6* and the green fluorescent protein (GFP) will be co-microinjected. Animals containing the extra-chromosomal array will be analyzed using Narmaski optics and immunohistochemical techniques.

Garrad, R.C.¹, F.A. Gonzalez² and G.A. Weisman³. ¹Biomedical Sciences Department, Southwest Missouri State University. ²Department of Chemistry, University of Puerto Rico. ³Department of Biochemistry, University of Missouri-Columbia. INHIBITION OF P2Y2 RECEPTOR DESENSITIZATION BY INHIBITION OF PROTEIN KINASE C ACTIVITY. UTP, which activates the G protein-coupled P2Y2 nucleotide receptor has been shown to stimulate calcium-activated anion secretion which can bypass the defect present in CF epithelia. Exposure to UTP desensitizes the P2Y2 receptor to further applications of agonist. The P2Y2 receptor signaling pathway activates PKC and activation of PKC by phorbol esters desensitizes the receptor. We have studied the effect of inhibiting PKC activity on receptor desensitization and sequestration. PKC activity was inhibited either by incubating with 500nM PMA overnight or by treating cells expressing P2Y2 receptors with varying concentrations of GF109203X, a specific PKC inhibitor. Incubation with GF109203X may increase receptor numbers on the cell surface and enable a greater response to a second challenge with UTP. These data suggest a role for PKC in the regulation of receptor cycling in the cell.

Gordon, A.R. Department of Biomedical Sciences, Southwest Missouri State University. IDENTIFYING AGING-RELATED GENES IN *DROSOPHILA MELANOGASTER*. Aging is a multifactorial process involving environmental and genetic components. Standard *Drosophila* culture techniques are non-selective for allelic variants of aging-related genes that are phenotypically expressed late in the adult life cycle. Laboratory populations exhibit a wide range of lifespan and associated biochemical parameters suggesting that individuals in aging populations are aging at different rates. In this study, longevity selection based on differences in phototoxic responses among aging adults was used to establish longer-lived and shorter-lived subpopulations. After five generations of selection, longevity differences persisted in subpopulations when maintained without selection. A shorter lifespan in males suggests that a number of aging-related genes are located on the large X-chromosome of *Drosophila*. Work is in progress to determine whether these populations show differences in selected biochemical characters related to aging, such as catalase and superoxide dismutase enzyme activity. Comparisons of specific allelic variants between short-lived and long-lived populations using the known *Drosophila* genome may help identify genes related to aging when the molecular details of their products are not yet known or identified.

Gordon, J.M. Department of Biomedical Sciences, Southwest Missouri State University. EFFECT OF 5-HYDROXYTRYPTAMINE ON CYTOSKELETAL CHANGES IN ENDOTHELIAL CELLS. It is known that inflammation leads to increased vascular permeability and extravasation of fluid from the capillary bed into the interstitial space. 5-Hydroxytryptamine (5-HT) released by platelets and other cells during inflammation has been found to cause endothelial cell (EC) retraction, resulting in increased intercellular gaps. This study was designed to explore the effect of 5-HT on the morphology of calf pulmonary artery ECs. Using actin-specific rhodamine phalloidin as a fluorescent marker, 5-HT-treated cells were found to have fewer actin filaments at the cell periphery, increased stress fiber formation, and smoother, denser edges than control cells. 5-HT-treated cells had less defined lamellipodia and filopodia than control cells, suggesting changes in the cytoskeleton. Cells pre-treated with SB 206553, a 5-HT receptor inhibitor, prior to 5-HT incubation showed morphology and actin distribution similar to control cells. This research suggests that 5-HT may have an effect on vascular permeability and extravasation at the EC level related to alteration of the actin cytoskeleton.

House, C. D. and Witkowski, C. M. Department of Biomedical Sciences, Southwest Missouri State University. POTENTIAL INSERTION OF THE GREEN FLUORESCENT PROTEIN CODING SEQUENCE INTO THE *C. ELEGANS* $\alpha 2(IV)$ COLLAGEN GENE. Type IV collagen is an important structural element in most basement membranes of *C. elegans*. The formation of type IV collagen networks is partly understood, but not easily visualized in vivo. This study was conducted to explore the potential of expressing type IV collagen tagged with green fluorescent protein in *C. elegans*. Published literature, database sequences, and computer alignments were used to identify interruptions of the Gly-X-Y triple-helical domain in the $\alpha 1$ and $\alpha 2$ subunits of type IV collagen. Computer-simulated restriction enzyme digests were used to identify potential restriction enzyme cut sites located within both genes. Based on the known structure and function of collagen, a restriction enzyme site occurring exactly once on the $\alpha 2(IV)$ gene and located within an interruption of the triple-helical domain was determined to be the best potential site for incorporation of the GFP sequence. Once successfully cloned, this recombinant gene will be used to rescue collagen IV null mutants, and we will be able to select for a functional tagged protein.

Hutcheson, C.J., C.M. Witkowski. Department of Cell and Molecular Biology, Southwest Missouri State University. ANALYSIS OF BODY WALL MUSCLE CELL SHAPE IN WILD-TYPE AND COLLAGEN IV MUTANT STRAINS OF *C. ELEGANS*. *C. elegans* body wall muscle cells organize and begin to function at an early stage during embryogenesis. Animals homozygous for a null allele of collagen IV lack this molecule in the basement membrane of muscle cells. These mutants show degeneration of muscle cell ultrastructure as early embryos and die during embryogenesis. The myofilament lattice collapse in these embryos has been analyzed by immunofluorescence with antibodies to myosin A and actin. Research is in progress to produce transgenic *C. elegans* worms (mutant and wild-type) that contain marker genes *rol-6* (*su1006*) and Green

Fluorescent Protein (GFP). GFP expression is driven by a muscle specific promoter from the $\beta 1$ integrin subunit and is targeted to the plasma membrane allowing GFP to tether to the cells and illuminate specifically muscle cell membranes in the worm. This study intends to determine whether these muscle cells show degeneration of shape or if they appear normal as compared to wild-type. The results should help determine what effect lack of collagen IV in the basement membrane has on muscle cell shape and organization of the longitudinal body wall muscle quadrants during degeneration of muscle cell ultrastructure.

Islam, M.R.,¹ M. Rodova² and J.P. Calvet². ¹Department of Chemistry/Physics, Northwest Missouri State University; ²Department of Biochemistry and Molecular Biology, University of Kansas Medical Center. DNA FRAGMENT ISOLATION FROM AGAROSE GELS WITHOUT USING COMMERCIAL KITS. Isolation of DNA fragments is an essential step prior to most cloning works. Several commercial kits available that allow molecular biologists efficient isolation of DNA fragments. Although prices of these kits are not so expensive, the costs are especially important in labs doing a lot of cloning works and in undergraduate teaching colleges/universities where budgets are limited. Here, we describe a fast and efficient method for the isolation of DNA fragments from agarose gels by simply employing centrifugation in microfuge tubes. The yield of linearized 2.95 kb pBluescript ran on 1% agarose in 1x Tris-acetate EDTA was 50%, employing either -20°C or -80°C incubations, compare to the 45-60% yields obtained using the "Quantum Prep Freeze 'N Squeeze DNA Gel Extraction Spin Columns" from Bio-Rad, and "GenElute Agarose Spin Columns" from Sigma. There was a significant amount of DNA left in the gel slices after the first centrifugation, which could be easily extracted in a small volume by a second centrifugation. The vector DNA isolated in this centrifugation method can be successfully treated with alkaline phosphatase, and ligase to clone a foreign 1.5 kb DNA fragment.

Langiano, L.G., C.M. Witkowski. Department of Cell and Molecular Biology, Southwest Missouri State University. PROPOSED CELL BINDING SITE ANALYSIS OF CAENORHABDITIS ELEGANS COLLAGEN IV. We are using *C. elegans* as a model organism to analyze the function of a conserved site on the collagen IV molecule. The assembled *C. elegans* molecule contains a sequence that is homologous to a cell-binding site (CBS) on the human molecule for integrin $\alpha 1\beta 1$. Our hypothesis is that this may also be an important CBS in *C. elegans*. We have used transgenic techniques to produce animals bearing a gene for the collagen $\alpha 1(\text{IV})$ chain containing a single point mutation at the proposed CBS in combination with marker genes *rol-6* (*su1006*) and Green Fluorescent Protein (GFP). Deletion mutations of the $\alpha 1(\text{IV})$ chain result in a lethal null phenotype. Preliminary data show the CBS mutant transgenes do not rescue the homozygous null animals, while control mutations do. Nomarsky optics and immunohistochemical techniques with antibodies to the $\alpha 2(\text{IV})$ chain, myosin heavy chain, and GFP are being used to analyze the phenotypic defects exhibited by homozygous animals with a CBS mutation. These animals arrest during embryogenesis and show loss of muscle structure, thereby characterizing the CBS as an important conserved feature.

Ralya, A., and C.M. Witkowski, Department of Biomedical Sciences, Southwest Missouri State University. ANALYSIS OF TRANSGENIC *C.ELEGANS* STRAINS. This project was undertaken to analyze the importance of a putative cell binding site (CBS) on the collagen IV molecule using *C. elegans* as a model for the human molecules. *C. elegans* is a non-parasitic nematode that exists either as a male or a self-fertilizing hermaphrodite, and its entire genome has already been sequenced. Collagen IV exists as two $\alpha 1$ chains and one $\alpha 2$ chain, and the human CBS contains conserved aspartate (D) residues on the $\alpha 1$ chains and an arginine (R) residue on the $\alpha 2$ chain. These three residues form a 3-dimensional D-R-D conformation that is recognized by the cell surface receptor. Transgenic nematodes were created by injecting three plasmids into the syncytial gonad of the hermaphrodites forming extra-chromosomal arrays. The experimental transgenic genotype was a point mutation of Asp(480) to Glu in the D-R-D site, and the control mutation was Asp(472) to Glu in a Gly-X-Y repeat upstream from the proposed CBS. The other two plasmids received in both injections were marker genes *rol-6*(*su1006*) and GFP. Transgenic progeny were then isolated and analyzed using immunofluorescence. Nematode cultures were kept on agar plates with OP-50 *E. coli* at 15°C and observed and manipulated under a stereomicroscope. Using these techniques, the function of the CBS can be analyzed.

Witkowski, C.M. Department of Biomedical Sciences, Southwest Missouri State University. USING RNAi TO IDENTIFY A CELL SURFACE RECEPTOR COLLAGEN TYPE IV IN *C. ELEGANS*. Collagen type IV is one of the most abundant proteins present in basement membranes. Highly conserved regions of this molecule point the importance in providing developmental cues for all organisms. Cells receive information from the underlying basement membrane through cell surface receptors that interact directly with the basement membrane proteins. In vertebrates, integrins are the cell surface receptors for collagen type IV. The model organism *C. elegans*, a free living soil worm, expresses collagen type IV. The goal of this research is to identify the *C.elegans* cell surface receptor for recognition of collagen type IV. Search of the *C.elegans* genome suggests this organism uses a different mechanism compared to vertebrates. Candidate genes have been identified by BLAST analysis and the reverse genetic technique of RNAi will be used to study these genes. RNAi uses short dRNA oligo-nucleotides to regions of expressed portions of genes to phenocopy a null mutation. Transgenic phenotypes expected will be similar to collagen type IV null animals. Using this model system to understand the functions of collagen type IV will help in understanding the developmental cues provided by collagen type IV. Supported by a SMSU Faculty Research Grant.

Computer Science

Chair Yang Wang

Martin, R.A., J.D. Martin. **Computer Science Department, Southwest Missouri State University.** INFORMATION TECHNOLOGY PROFILE OF MISSOURI'S SECONDARY SCHOOLS. The purpose of the study was to gauge the level of information technology courses being taught in Missouri's secondary schools. Surveys were mailed to 498 Missouri high schools in February 2001. Follow-ups were done via e-mail one month after the surveys were mailed. A total of 321 surveys were returned for a response rate of 64%. This is an unusually good response rate for a mail survey and suggests a high degree of interest in information technology issues. Most schools offered courses in keyboarding and computer literacy, while few offered AP Intro Computer Science courses. Nearly half of the schools (45%) indicated that their schools did not offer programming courses. The most widely taught skill was word processing, followed by electronic spreadsheet and desktop publishing. Ethical issues were least likely to be taught. Each school was given a technology score based on the number of courses and skills taught. Scores ranged from 2 to 15. Significant differences were found by enrollment and urban/rural status. Among larger schools, 70% had technology scores of 11 or above, compared to 47% or less for smaller schools ($p < .005$). Scores of 11 or above were more likely to be found in urban schools (59%) than rural schools (44%), $p < .01$. Virtually all of the responding schools reported that they offered some information technology courses. However, the number and type of courses, as well as the skills taught, varied widely.

Naugler, D. R., Department of Computer Science, Southeast Missouri State University. FUNCTIONAL PROGRAMMING IN JAVA. In functional languages such as Scheme or SML functions can be passed as parameters, can be constructed in other functions and returned as values. This allows a style of programming that is quite distinct from the that used with languages such as Pascal, C or C++. Superficially, Java has no functions; however, using interfaces and the inner classes that have fairly recently been added to the Java language it is fairly easy to mimic some of the features of functional programming. Using an interface for real functions, it is shown how to write functions that take functions as parameters and construct and return new functions. Both simple examples (such as creating a function which is the sum of two functions given as parameters, or creating the composition of two functions) and more complex examples such as generating a function representing the a finite number of terms of a Fourier series given the coefficients, and generating a function which is an approximation to an indefinite integral of a given function are shown. It is not advocated that functional programming be taught in Java—languages such as SML are much superior for that task. Rather, students can use modes of thinking learned in a study of a functional languages directly in programmes written in Java.

Naugler, D. R., Department of Computer Science, Southeast Missouri State University. THE ROLE OF THEORY IN THE UNDERGRADUATE COMPUTER SCIENCE CURRICULUM. Opinion among computer science teachers on the role of theory in the undergraduate computer science curriculum differs widely. Since such teachers may come from highly varied backgrounds and from distinctly different educational generations, there is not any easy consensus on what, precisely, theory is, let alone on its role in undergraduate education. Indeed a given instructor in a given course may be viewed as too theoretical by one colleague and too "hands-on" by another. The Computer Science discipline has its roots in both the mathematical and the engineering sciences; it has resemblances to both yet is clearly neither one. Many Computer Science teachers were originally in one or the other of these areas. The notion of theory and its role in undergraduate Computer Science Education is explored starting with views expressed by a selection of the field's founding practitioners, some of whom are still active teachers. Whatever theory is, its main purpose should be to directly or indirectly inform practice. It is noted that in a discipline as relatively new as computer science a divergence of opinion on the role of theory is to be expected and is probably healthy.

Shade, E. **Computer Science Department, Southwest Missouri State University.** LANGUAGES + INTERPRETERS + AUTOMATA + COMPUTABILITY = THEORY OF COMPUTATION. Computer science programs traditionally include courses both in programming languages and theory of computation. Theory of computation is important, but it is normally taught using a theorem/proof approach, and in my experience this causes many students to miss the point. I prefer a more applied approach where the theory is used to build useful programs. Programming languages are important, but it is not clear that we need an entire course devoted to the subject, especially since popular languages like C++ and Java already contain virtually all the imperative features typically covered in such a course. What remains is alternative programming paradigms like functional and logic programming, and material related to the implementation of programming languages. But I use a functional language in theory of computation, and many of the applications are interpreters for small languages. Because of this overlap, I propose replacing these two three-hour courses with a single four-hour course. It will be a better course and will free up space in the curriculum.

Wang, Y. **Department of Computer Science, Southwest Missouri State University.** A COMPARISON OF EASTERN AND WESTERN EDUCATIONAL EXPERIENCES. Statistics have shown that American students at many levels do not do as well on tests of mathematical and scientific achievement as some of their foreign counterparts, most notably in Asia. Their former superior position on practical problem solving abilities seems to be slipping gradually also. This situation has caught the attention of many educators from the elementary level to the university. In order to provide students the best education possible and to continuously improve the quality of the education system in the United States, it is necessary to find the strengths and the weaknesses of the system, compared with other education systems. In this paper, the author, who has taught in universities in both

China and the United States for a number of years, compares the educational experiences with these two different education systems. Some major differences in the Western and Eastern educational philosophies, such as emphasizing theoretic subjects vs. practical subjects, are discussed. Other less well-known differences in the training and facilitation processes of teachers of higher education are pointed out. Variations in the teaching practices of the two countries are also mentioned.

Conservation Section

Chair Cary D. Chevalier

Ashley, D. C. Department of Biology, Missouri Western State College. SPHINGID BIODIVERSITY AT FIVE NORTHWEST MISSOURI PRAIRIES. Field studies in 2001 focused on the biodiversity of hawkmoths found at five locations in northwest Missouri. These studies were conducted in conjunction with studies on the natural history of a prairie orchid (*Platanthera praeclara*) occurring at three of the prairies. Insects were collected at Helton Prairie Natural History Area (Harrison Co.), Tarkio Prairie Natural History Area (Atchison Co.), Little Tark Prairie Natural History Area (Holt Co.), Pawnee Prairie Natural History Area (Harrison Co.) and Dunn Ranch (Harrison Co.). Moths were collected from light traps (black-light bucket traps) deployed between June 11 and June 15 and again deployed on August 25 and August 26. Three traps were placed on each prairie and specimens were collected for two successive nights at each prairie. Fourteen species of sphingid moths were collected during the course of this study. Individuals specimens collected in any trap night ranged from 0 to 26. The most common hawkmoth encountered during the study was *Ceratomia hageni*. The hawkmoth diversity was greatest at Helton Prairie and lowest at Pawnee Prairie. This study was funded in part by the MDC Natural History Small Grants.

Ashley, D. C. Department of Biology, Missouri Western State College. POTENTIAL POLLINATORS OF A STATE-ENDANGERED PRAIRIE ORCHID. Little is known about the pollination biology of the White Fringed Prairie Orchid (*Platanthera praeclara*) at its three current locations in Missouri. During the 2001 flowering period, I completed approximately 30 hours of field observation on plants at Tarkio Prairie Natural History Area (Atchison Co.) and Little Tark Prairie Natural History Area (Holt Co.). I observed twelve visitation events at flowering orchids by moths of the family Sphingidae. I was able to collect five of these moth specimens. Two individuals of *Manduca sexta* and one individual each of *Manduca quinquemaculata*, *Paratraea plebeja* and *Sphinx eremitis* were collected. The specimen of *P. plebeja* was the only moth collected to have orchid pollinia on its body. I was unable to collect 7 of the hawkmoth visitors. Three of these visitors were probably species of *Manduca*. The other four appeared more similar to species of *Sphinx*, although identification is not possible without the specimens. This study was funded in part by the MDC Natural History Small Grants Program.

Dean, K. L. Department of Biology, Central Missouri State University. PHYSIOLOGICAL CONDITION, DIETARY AVAILABILITY AND CHOICE FOR NEOTROPICAL WOODLAND MIGRANTS AT RIPARIAN STOPOVER SITES IN SOUTHEASTERN SOUTH DAKOTA. The physiological condition and selection of forage items by Neotropical woodland migrants at inland stopover sites is poorly understood. Seasonal variations in forage items do occur, and the ability to track this variation may enhance individual survival, and reproductive potential. I monitored seasonal variation in physiological condition, arthropod availability, and dietary choice for fat and lean migrants.

Seasonal comparisons in physiological condition were made using two measures: average fat score and energetic condition index (ECI=folded wing chord/mass). Individuals were categorized as fat, or lean, based on average fat scores. Lean individuals were exceedingly rare during spring migration (19.2% of population) but comprised a much greater proportion (38.0%) during fall migration. Eight species exhibited significantly higher spring than fall fat scores however no species was observed with higher fall fat scores. Eight species possessed greater spring ECI values and two species (Gray Catbird and Warbling Vireo) exhibited a significantly greater fall ECI.

Fall arthropod abundance was higher than spring (5.4 arthropods/0.5m branch and 2.7 arthropods/0.5m branch respectively) with spring availability remaining below fall levels until the third week of May. Neither lean nor fat migrants used arthropods in proportion to their occurrence. No significant overlap in diet between physiological groups was observed in either season and lean birds had higher dietary diversities during both seasons. Both physiological groups ingested fruit, however fat birds ate proportionally more fruit. This may be related to alterations in gut size resulting from differential fasting periods.

Elliott, W.R. Natural History Division, Missouri Department of Conservation. THE CONSERVATION OF MISSOURI CAVE BATS. The decline of Indiana bats, *Myotis sodalis*, and Gray bats, *M. grisescens*, often is linked to human disturbance of their cave roosts. Significant bat conservation work began in Missouri in the 1970s with bat studies and the rejection of the proposed Meramec dam, which would have inundated many caves. State and federal agencies have since monitored bat colonies, documenting drastic declines in both species and then the partial recovery of *M. grisescens*. Early cave gates were sometimes flimsy or unsuitable. Modern, air-flow, bat-friendly gates are stronger and come in different styles, which will be illustrated. There is a link between archaeological looting of caves and bat disturbances. Two looted caves that were gated in 2001 had prompt increases in their Gray bat populations. Proper management requires following a decision guide before a cave is selected for gating. Only a small percentage of caves need to be gated to protect bats and other resources, but the number is increasing because of increasing pressure on caves. Examination of historical weather data and three years of temperature data logs in seven caves and one mine have indicated a possible warming trend in Indiana bat hibernacula. The mean annual temperature has not changed much, but extreme winter lows are warmer than 20 years ago. Some species require a cold-air-trap cave that receives surges of heavy, cold air. The premier *M. sodalis* hiber-

naeculum is now Pilot Knob Mine, which is below 8°C throughout the year and is secure from intruders.

Goins, R. C. McCabe and C. D. Chevalier. Department of Biology, Missouri Western State College. USING GPS AND GIS TO ESTABLISH PERMANENT BIODIVERSITY SURVEY/MONITORING GRIDS AND CONSTRUCT UPDATEABLE VEGETATION MAPS: AN EXAMPLE OF USING GEOSPACIAL TECHNOLOGY AS A NON-TRADITIONAL LEARNING EXPERIENCE FOR UNDERGRADUATE EDUCATION IN NATURAL RESOURCES CONSERVATION. Two 60 by 80 meter grids were established and mapped using GPS units (Trimble Navigation Ltd.) with Real-time Differential GPS technology (Omnistar USA Inc.) in the Biological Study Area on campus at Missouri Western State College. One grid was established next to Oto Creek in established undisturbed riparian forest. The other was located upland in a portion of the study area that had been pasture in the past and is in successional re-establishment of forest. We recorded the location, using Real-time Differential GPS, species, and DBH of all trees of DBH > 15 cm. The grid dataset and tree map dataset were then exported to a GIS program (ArcView 8.2) for special analysis and production of a vegetation map. These datasets now make it possible to monitor long-term dynamics in tree species biodiversity and spatial distribution along a north-south gradient from adjacent to Oto Creek to the northern upland secondary successional areas on the Biological Study Area. In the future, we plan to extend these datasets to encompass the entire Biological Study Area on Campus. These monitoring/survey grid systems and the vegetation maps we can produce will provide educational opportunities for a broad range of students at MWSC from non-major biology to those specializing in conservation biology and other areas of organismal biology.

Heth, Robert K. Department of Biology, Missouri Southern State College. EFFECT OF TENKILLER RESERVOIR TAILWATER FLOW REGIME ON BENTHIC INVERTEBRATES. Hypolimnetic release from reservoirs can have severe effects on downstream biota. This study investigated effects of enhanced flow to mitigate low dissolved oxygen levels below an eastern Oklahoma reservoir. Benthic invertebrates were sampled at reference site above dam and two below sites both before flow was enhanced (1996-98) and post enhancement (2000). Fifty-five taxa were collected at reference site, predominantly mayflies (19 species). Twenty-seven and twenty-eight taxa were collected at two tailwater sites. Shannon-Weaver diversity at reference site averaged 2.16 (SE \pm 0.10) and at two tailwater sites 1.18 (SE \pm 0.03) and 1.15 (SE \pm 0.05). Jaccard Community Similarity between reference and tailwater communities was low (31% and 24%). Tailwater communities were dominated by small oligochaetes, chironomids, snails, and crustaceans (*Lirceus* and *Caecidotea* spp). Tailwater sites were notable for loss of sensitive insect taxa, especially among mayflies and stoneflies. Biotic index values at all sites were significantly different ($p < .0001$). Effect of flow enhancement on biotic index values was marginally significant ($p < .048$), however flow by site interaction was highly significant ($p < .0002$). Changes in primary production, flow regime, and temperature patterns are hypothesized to provide as great an impact as does dissolved oxygen on tailwater benthic communities.

Marquardt, S. R., and C.A. Schmidt. Department of Biology, Central Missouri State University. CORRELATES OF URBANIZATION AND USE OF URBAN HABITAT BY BATS. Urban development often results in a reduction of natural areas, an increase in the number of artificial light sources, an increase in human population density that results in more man-made structures, and expansion in total area as well as changes in the general shape of the city. It is important to determine how urbanization and human activity impact bat communities because bats are sensitive indicators of ecosystem health. The goal of this study is to examine the relationship between urbanization factors and bat activity within urban areas. Seven cities in Missouri were chosen as sampling locations based on population size and general shape. A total of eight monitoring sites (outer zone: sites 1-4; inner zone: sites 5-8) were selected in a circular pattern within each city. Using broad-band ultrasound detectors two research teams recorded the number of bat passes observed at each site. The total number of bat passes and the number of passes in each sampling zone was regressed against six urbanization factors. Of the factors considered in this study, the strongest associations were between the number of passes in the outer zone and both percentage of agricultural land (positive association) and percentage of forested land (negative association). These associations suggest that even though streetlights may provide concentrations of prey species, bats still use forested areas extensively to forage. Under this scenario, as agricultural land replaces suitable forest habitat, bats would shift some of their foraging activity to the clusters of insects attracted to the city lights.

Nold, L., J. Casey, B. Porrier and J. Rushin. Department of Biology, Missouri Western State College. FOREST REGENERATION AFTER UNEVEN-AGED MANAGEMENT AND CLEAR CUT HARVESTS AT THE BLUFFWOODS CONSERVATION AREA IN BUCHANAN COUNTY, MISSOURI. This study utilizes a Missouri Ozark Forest Ecosystem Project sampling method along a single 3,500 foot transect to compare trees over one inch DBH and seedlings under one inch DBH before and after the following treatments: uneven-aged management (9 sampling points), clear cut (8) and no treatment (19) harvest methods. All 36 sampling points along the transect were originally determined and the entire transect was surveyed under pre-harvest conditions during the growing season of 1998. Post harvest surveys were conducted in 2001. Pre-harvest (1998) importance values showed the transect to have a section of 3 sampling points in old growth forest dominated by red oaks, ironwoods, sugar maples and hackberry with red elm and ash showing the greatest seedling densities. Pre-harvest importance values showed the remaining 33 sampling points on the transect to be successional forest dominated by sugar maples, red elm, hackberry, chestnut oak and basswood with red elm, staph tree, paw paw, hackberry and ash showing the greatest seedling densities. Although importance values showed that the dominant trees in the no treatment (control) section of the transect to be essentially unchanged from pre-harvest (1998) to post harvest (2001) surveys, there were some small but noticeable shifts in seedling distribution along this successional section of the transect. Based on importance values, the uneven-aged management section of the transect showed little change in dominant species from the original successional forest but there were some noticeable shifts in

both seedling distribution and seedling densities. Significant changes were observed in both dominant species and seedling densities in the clear cut section from pre-harvest (1998) to post harvest (2001). Especially in 2001, non-canopy tree species such as red elm, ironwood, rough-leaved dogwood and paw paw were dominant in the clear cut section. Seedling densities and overall seedling diversity were much greater after the harvest in the clear cut section of the transect. Red elm, ash, hackberry, chestnut oak and Ohio buckeye showed the greatest seedling densities after clear cut harvest but red oaks and sugar maple seedling were also found on this section. A total of 21 tree species were sampled during this study. Support by the Missouri Department of Conservation.

Engineering

Chair: Virendra K. Varma

Cox, N.R., B.H. Chowdhury, and C.H. Wu. Department of Electrical and Computer Engineering, University of Missouri-Rolla. PHOTOVOLTAIC SYSTEMS ENGINEERING: A MULTIFACETED DESIGN COURSE WITH A BRIGHT FUTURE. With recent power shortages on the West Coast and mounting concerns over Arctic drilling, Americans are again considering the potential role of alternative sources of energy. This paper discusses the development of a new senior/graduate-level photovoltaic systems course that addresses all aspects of designing complete stand-alone and utility-interconnected solar electric systems. The course addresses a broad range of topics ranging from the solid-state theory of photovoltaic cell technologies to the structural considerations and mechanical stresses that accompany the use of commercially manufactured solar panels. Additional topics include solar radiation measurements, site evaluation, selection and sizing of commercial components and materials, control electronics, building codes and regulations, economic analysis, and how to best combine this technology with other energy sources. This course lends itself well to interdisciplinary team projects, and presents an excellent opportunity for students to apply their knowledge in solving a real-world problem. It instills an awareness of national energy issues as well as a sense of how engineering is carried out in practice.

Pashaie, B. and D. Randolph. Department of Engineering-Physics, Southeast Missouri State University. DETERMINATION OF FRACTAL DIMENSION FOR SOUTHEAST MISSOURI REGION SEISMIC ZONE. Seismic activity below the New Madrid region is not frequent, but significant. It is essential that the time of arrival of seismic wavefronts be known to assist in the study of subsurface seismic velocity structure. Recent addition of broadband sensors in the local vicinity makes automated detection possible. Such data is available from the United States Geological Survey in Golden-Colorado. A UNIX system was setup to download and decode the seismic data. The Chaos Data Analyzer developed by J. C. Sprott and G. Rowlands at the University of Wisconsin was used to determine the Fractal-Dimension of the decoded data. The development of a fine-tuned Random-Walk algorithm is beginning. In seismic applications, the power-law behavior of the signal properties is

common to all seismic zones. However, the magnitude of the Dimension is unique to the particular location of interest.

Sauer, H.J., Jr. and C. Nunez. Department of Mechanical and Aerospace Engineering and Engineering Mechanics, University of Missouri-Rolla. TEMPERATURE AND THERMAL CONDUCTIVITY OF MISSOURI SOILS. Temperature and thermal properties of below grade soil significantly affect the heat transfer to and from surfaces and bodies below grade level. Most previous data have been obtained less than a foot from the earth's surface and are not very useful for heat transfer estimates with most underground installations. Several models exist for predicting the ground temperature as a function of time of year, depth below surface, and type of soil. This project included measuring both temperature and thermal conductivity of soil at various depths below ground level. Temperature measurements were recorded hourly over a two year period. Results show that it is possible to predict the sinusoidal behavior of ground temperatures with reasonable accuracy once the type of soil has been determined (e.g., clay, sand, silt,...) and normal weather bureau air temperatures are available. The results should prove useful for both design and estimation purposes with such applications as underground transmission lines, ground source heat pumps, buried piping systems, energy loss/gain from below grade walls and floors of buildings, ice prevention systems for roadways, and other industrial applications of geothermal energy. Support was provided by Ameren-UE.

Varma, T. Department of Curriculum and Instruction, Northwest Missouri State University. SIGNIFICANCE OF TEACHING ENGINEERING IN GRADES K-12 TO ENHANCE MATH AND SCIENCE EDUCATION. In the United States, eighty-two percent of 12th graders are not proficient in science and seventy-two percent of 8th graders are not proficient in mathematics. At a time when there is a shortage of engineers in the U.S., and every industry is going high-tech, there is a tremendous need for increasing awareness of engineering as a profession, and enhancement of math and science education in grades K-12. To enhance the math and science scores of students, Massachusetts Board of Education has voted unanimously to require that engineering be taught in grades K-12, and has created a new curriculum framework to be used by all schools in the state. The public today is demanding consistent quality of goods and services, and education that is responsive to changes in technology and employer needs. Colleges and universities are being held to higher standards of accountability in regard to basic skills of graduates in the areas of problem-solving, critical thinking, and communications. This paper addresses the need for a shift in math and science policy of K-12 schools to develop strong fundamentals of students in mathematics and science. It also addresses school-college partnership programs for enhancement of math and science educational programs.

Exercise Physiology

Chair: Janice E. Nelsen

O'Hara, A.L. and Wilson, D.J. Department of Health, Physical Education, and Recreation, Southwest Missouri State University. THE EFFECTS OF PUSH-OFF FORCES ON BASEBALL PITCHERS' VELOCITY. The purpose of this study was to investigate the relationship between the peak posterior force (PPF) and peak vertical force (PVF) produced by professional baseball pitchers to the velocity of their pitches. Six minor-league pitchers each threw ten pitches from a wooden pitching mound in an indoor gymnasium. A force platform was placed in the mound to measure forces produced during the delivery. Velocity data was measured using a radar gun positioned behind the target. Twenty-three (N=23) total pitches were analyzed, with at least three coming from each subject. A statistically significant correlation ($r = 0.518$) was found between the PPF and ball velocity ($p < 0.05$). A statistically significant correlation ($r = 0.641$) was also found between the PVF and ball velocity ($p < 0.01$). The greater posterior and vertical forces produced by the professional baseball pitchers during the delivery seem to produce higher velocity measurements. The discussion will center on the relationship between forces produced during the delivery and the resulting ball velocity.

Stalhood, C.S. and D.J. Wilson. Department of Health, Physical Education, and Recreation, Southwest Missouri State University. STEP AND STRIDE, AND STEP AND NO STRIDE BASEBALL BAT SWINGS VS. BAT VELOCITY. The purpose of this study was to determine the relationship between two batting methods (stride step and step without stride) and the resulting bat velocity. Twenty subjects, with at least a high school level of baseball experience were recruited for this study. Each subject in random order performed three trials of each batting method. Video data was collected using a 240-hertz camera positioned above a basketball goal. The images were digitized using an automated kinematic analysis system that calculated three-dimensional coordinate data. An analysis of variance (ANOVA) was performed with the angular velocity of the bat and wrists as main effects. Statistical results will be discussed in the context of coaching methods and batting preferences of the players.

Worthington, C.D. and D.J. Wilson. Department of Health, Physical Education, and Recreation, Southwest Missouri State University. EFFECTIVENESS OF TECHNOLOGY IN A KINESIOLOGY CLASSROOM. This study investigated the effectiveness of a videodisk instructional tool. The National Association for Sport and Physical Education (NASPE) recommends that technological tools, like videodisks, are important supplements to classroom lectures. However, there is little scientific evidence that these tools improve learning or enjoyment. Undergraduate college students who were enrolled in back-to-back spring semesters of a kinesiology class served as subjects for the study. The experimental group completed three videodisk-teaching sessions beyond the normal classroom sessions. Measures taken for the study included (1) performance on a standard biomechanics test, and (2) a self-rated questionnaire about

perceptions of learning and enjoyment relating to biomechanics. Students who did not receive video instruction rated their knowledge higher than those students who did receive video instruction. Conclusions included the possibility that student interest and motivation may have a greater role in both performance and enjoyment than instructional method. Several limitations to the study were noted and discussed as part of the need for further investigation.

Geography

Chair: Tom McCray

Cooper, R. M. Department of Geography, University of Missouri-Columbia. LANDSCAPE REPRESENTATIONS OF THE CURRENT AND JACKS FORK RIVERWAYS. The purpose of this paper is to examine the role that representations of the landscape of the Current and Jacks Fork Riverways played in the political struggle over these rivers and their surrounds. The Current River region of the southeastern Missouri Ozarks was one of the nation's largest and most important lumbering areas in the late 19th and early 20th centuries. The numerous lumbering operations removed almost all of the marketable timber and heavily transformed the landscape of the region. Yet, less than 20 years after the last recorded log drive on the Current River, a variety of individuals, environmental organizations, and government agencies were calling for the federal protection of the Current and Jacks Fork rivers and the creation of a national recreation area based on the many natural and scenic qualities of this landscape. A bitter political battle involving a variety of individuals and groups ensued, culminating in 1964 with the establishment of the Ozark National Scenic Riverways, America's first federally protected riverine park. The focus of this study is on the portrayal of the landscape as being natural and wild. The representations are placed in their historical and political contexts, following recent research in cultural geography that challenges the idea of mimetic representation. This study illustrates the conflicting and often contradictory ways in which the landscape of the Current and Jacks Fork Riverways was represented and shows that landscapes and their representations are not divorced from ideologies.

Hamilton, J.H., Department of Geography, University of Missouri-Columbia. SHORTLEAF PINE DISTRIBUTION IN THE OZARK CURRENT RIVER HILLS. Historically, the forests of the Ozark Current River Hills had a large shortleaf pine (*Pinus echinata*) component. In the early 1900's much of the region was logged. Oak and hickory (*Quercus* and *Carya* spp.) forests have grown in place of the removed pine. This study will evaluate the historic distribution of pine based on the notes made by the Public Land Survey in the early 1800's. The historic distribution will be compared to the current distribution of pine to identify areas where the forest cover has significantly changed. The current distribution of pine will be obtained from multiple sources including Forest Inventory and Analysis plots and Landsat Thematic Mapper images. The geographic and ecological factors of slope, aspect, geology, soils, and landform will be evaluated in conjunction with pine plots to determine the set of factors that historically supported pine forests and will be compared to the modern land cover types that currently occupy these sites.

Jungmeyer, R., Division of Social and Behavioral Sciences, Lincoln University. THE HISTORICAL GEOGRAPHY OF AN HBCU: LINCOLN UNIVERSITY. This study focused on the geographic, historic, and political factors in the decision to locate Lincoln University in Jefferson City, Missouri, as opposed to Kansas City or St. Louis. The idea to establish an educational institution in Missouri for the benefit of freed blacks came from a group of enlisted men and their white officers that served in the 62nd and 65th Colored Infantries. As this idea moved toward fruition it appeared that such an institution might be located in St. Louis, where the majority of the state's black population resided. Due to political forces this plan failed, making the committee for establishing Lincoln Institute, turn their attention to Jefferson City. With Governor Thomas B. Fletcher and the state government being supportive of the Union cause, Lincoln Institute was established in Jefferson City, Missouri, in 1866.

Jindrich, J.B. Department of Geography, University of Missouri-Columbia. IDENTIFYING ELEMENTS OF RACIAL SEGREGATION IN A HISTORIC G.I.S. This study uses data from Columbia city directories spanning the years 1905-25 to identify the extent, block location, and general demographic location of the separate colored community in relation to the neighboring majority white community. A primary reason for this research is to examine the relationship of the historic Black community to specific environmental conditions. Various transformations were applied to the data to verify the accuracy of the model against contemporary records, as well as to identify patterns of residential density and relative affluence. The results suggest that the model is robust at the street block level, with counts of population very close to census records, and allowing a much finer degree of analysis. Data to support assertions of relative affluence were derived from tax and charity records. The study suggests a strong relationship between the flood plain of Flat Branch Creek with the location of the Black community as well as poverty in the White community, and pollution hazards. This result supports assertions by some authors that marginal land was an important factor in the location of Black populations within urban settings, locations that increased environmental hazards.

McCray, T.R. Department of Geography, Central Missouri State University. REVISITING TRANSPORTATIONS COMPETITIVE ERA. Nothing defines the United States or propels the American lifestyle like transportation. And no less impactful than the movement of people and ideas has been the shipping of goods. An important paradigm, first advanced by Edward Taaffe in the 1960s, organized the history of U.S. transportation into a series of Eras. With the latest—the post-war *Competition Era*, the United States achieved critical size and integration of its highway, rail, barge, pipeline and air facilities, so that conditions would encourage transportation consumers toward their most rational and efficient choices of freight movement. But a series of direct and indirect subsidies has subverted rational competition, beneath layers of social biases and extensive economic policies, so that today's most popular freight transportation choices—primarily toward the highway—are non-competitive in terms of real transport cost, vulnerable to disruption, and expose the environment and public safety to significant dangers.

***Salter, Christopher L. Department of Geography, University of Missouri-Columbia.** A ' REVIEW COMMENT ON GEOGRAPHIC INTERACTION AT THE MISSOURI ACADEMY OF SCIENCES. As I conclude more than a decade of presence and presentation at the Geography Section of the MAS Annual Meetings, it seems useful to review the nature of these sessions. For faculty members, graduate and undergraduate students these Sections have provided an excellent forum for geographic interaction. The small size of the house, the high level of interest in making the forum interactive for productive discussion, even argument, and the diverse nature of the topics brought to the floor here has meant that every dedicated participant has seen a microcosm of professional group dynamics. The Geography Section is peopled both by very senior faculty and just-starting grad (and even undergraduate) students. It has been a relatively benign setting for the prompting of serious first presentations. It has been a forum for the reflection on a whole career of field explorations. It has been a Section that has a self-reliance that is good for geographers but somewhat confusing for the MAS because of the customary Friday night dinner for all Section Presenters. This paper will outline the ways in which the MAS event diverges from presentation settings at Regional and National professional meetings, highlighting the aspects of the MAS experience that help build a sense of productive community within a (too, too) small corps of Missouri geographers.

Wilford-Hammett, R.E. Department of Geography, University of Missouri-Columbia. FINDING MEANING IN A LANDSCAPE OF STONE: THE WOMEN OF BELLE-FONTAINE CEMETERY. Previous research has neglected to study the association of nineteenth century rural park cemeteries with statues of women as memorials. Bellefontaine Cemetery in St. Louis, Missouri was established in 1849 as part of the rural park cemetery movement; a movement recognized for its picturesque landscapes and elaborate memorials. QUAN-QUAL mixed methodology was used in this necrogeographic endeavor to consider general spatial and temporal patterns as well as unique local factors which contributed to the presence of figures of women at Bellefontaine Cemetery. A survey of Bellefontaine Cemetery was completed establishing the locations of over 100 statues of women. The statues were photographed, mapped, classified, and coded for themes of meaning while records and documents were used to analyze demographic information about individuals and families who are memorialized by these figures. As material culture, these statues have been interpreted in four interconnected phases based on material, social, economic, and conceptual relationships. Content analysis of the material attributes of the statues shows that symbolically, the statues represent at least six broad, cultural conceptions of death. Closer evaluation of social and economic relationships indicates that while over-arching cultural meanings do exist, conceptions of death and the meanings embodied in the sculptures of women at Bellefontaine Cemetery do not prescribe to a cultural "norm."

Wilson E.W. Department of Geography, University of Missouri. POLITICS AND THE "LAND ETHIC:" A CASE STUDY OF THE PROPOSED ELK REINTRODUCTION IN MISSOURI. In 1999, the Missouri Department of Conservation performed a feasibility study to determine if elk could be reintroduced into the state. Although the potential release area was found to be ecologically suitable for elk, there was a substantial social backlash when the interests of sportsmen, farm bureau members, cattlemen, conservationists, environmentalists and locals clashed. This study explores the contradictions, noted by Aldo Leopold, between government-instituted conservation measures and individual environmental ethics, which are at the root of this controversy. The proposed reintroduction came on the heels of several proposed conservation initiatives; the Man and the Biosphere reserve, Coordinated Resource Management, and the reintroduction of the river otter, all of which are extremely unpopular in rural Ozark Missouri. This study takes a qualitative approach to assessing and voicing the disparate perspectives surrounding the elk debate, through semi-structured, open-ended interviews of individuals involved in the controversy. The findings suggest that the entire reintroduction effort was wrought with both politics and emotion. I argue that the conflict between stakeholders in this debate exemplifies the dilemma described by Leopold, and that resistance to biodiversity efforts must be taken seriously. Successful application of Leopold's Land Ethic in land management decisions will be more likely if the varied perspectives are all considered.

Geology and Geophysics

Chair: David Wronkiewicz

Dudley, M.A., J.L. Nold, and D. Joseph. Department of Earth Science, Central Missouri State University. THE CEDAR HILL DEPOSIT, IRON COUNTY, MO--A PROTEROZOIC OOLITIC SEDIMENTARY BANDED IRON FORMATION. At the Cedar Hill iron deposit north of Pilot Knob, MO, hematite ores are contained within rhyolitic volcanic breccias of the Proterozoic St. Francois Mountains terrane. These hematite ores show excellent thin bedding and lamination. These ores are alternating laminations of fine grained hematite and oolitic hematite, both with interstitial quartz., i.e., the ores are siliceous taconite banded iron formations. The oolitic nature of some of the laminations leads us to the conclusion that the bedded hematite ores are of undoubted sedimentary origin and not of hydrothermal replacement origin. In addition to the interbedded fine grained and oolitic ores, some of the iron is present as coarse, crosscutting specular hematite, filling fractures and breccia interstices, and apparently is of late hydrothermal origin. Associated with this late specular hematite is abundant red jasperoid, perhaps the result of hot spring activity. The bedded ores are, in places, considerably disturbed as a result of volcanic or tectonic processes. Minor magnetite is present and some has been partly converted to hematite as martite. Minor pyrite is also present. The laminated fine grained hematite ores at Cedar Hill are very similar in appearance to the ores at Pilot Knob Hematite. No oolites have been found at Pilot Knob Hematite but the similarity of the Pilot Knob ores to the fine grained ores at Cedar Hill

which are undoubtedly of sedimentary origin, strongly supports our past assertions that Pilot Knob Hematite is of sedimentary origin and not of hydrothermal replacement origin.

Reese, J.F. Department of Geology and Geography, Northwest Missouri State University. USING SPACE PHOTOS TO OBSERVE EARTH'S DYNAMIC SURFACE. Photographs of Earth from Space are excellent observational data that document large-scale earth-system processes and interactions as well as natural environmental changes and hazards. In essence, these photos show Earth's spheres operating on enormous scales. Photos of reefs, atolls, and algal/planktonic build-ups demonstrate a biosphere intimately connected with the hydrosphere and geosphere. Those of deltas show sediment input into the hydrosphere. Canyon landscapes and glaciated terrains as viewed from Space reveal modification of the geosphere by the hydrosphere. Photos of weather patterns and circulation systems depict dynamic linkage between atmosphere and hydrosphere. Photos of volcanoes and dust blows illustrate contrasting inputs of material into the atmosphere. Lake-level fluctuations documented from Space indicate short-term environmental changes. Tectonic elements such as mountain belts, volcanic arcs, rifts and faults, however, are linked to slower internal Earth processes and are clearly shown on photos. Impact crater photos reveal landscape modification by extraterrestrial agents. All of these photos portray complex yet clear interrelationships between Earth's spheres at scales best viewed from Space.

Physics

Chair: Jai N. Dahiya

Miller, D. D., Department of Chemistry and Physics, Central Missouri State University. USE of WEB-BASED PRE-LABORATORY ACTIVITIES FOR A GENERAL STUDIES PHYSICS COURSE. The vagaries of the General Studies Program at CMSU require that the course, *Introduction to the sciences: Physics*, be offered with and without a laboratory component. Very often the lecture portions of these courses are combined as well as being not closely correlated with the laboratories, which have multiple offerings per week. Several modules were developed which I provide information such as topic background, pictures of the attendant apparatus, and appropriate caveats. This information is the encoded into stand-alone HTML documents and made available on laboratory computers as well as the campus network. The students are expected to view these documents and "leave tracks" of their presence within a specified time before attending the laboratory.

Kapoor, Y.M. Division of Agriculture, Natural Sciences and Mathematics, Lincoln University. APPLICATION OF SMALL ANGLE X-RAY SCATTERING MODEL TO TWO LENGTH SCALE STRUCTURE IN GELS. Number of silica xerogels were produced using acid hydrolysis of tetramethyl orthosilicate for different water silane ratios. The scattering equation developed to analyze the intensity scattered by agglomerates and interacting scatters was used to analyze the scattering data from these gels. The analysis revealed that these gels were agglomerates of interacting scatterers (i.e. primary particles) with

average diameters ranging from 10Å to 55Å. The average diameters of the agglomerates were found to be between about 1000Å and 3000Å. Rough estimates of the number of scatterers in agglomerate could also be calculated.

SEVERAL EQUATIONS DIDN'T TRANSLATE@@@

Pashaie, Bijan, Physics Department, Southeast Missouri State University. THE DETERMINATION OF THE FRACTAL-DIMENSION FOR THE SOUTHEAST MISSOURI REGION SEISMIC ZONE. Seismic activity below the New Madrid region is not frequent, but significant. It is essential that the time of arrival of seismic wavefronts be known to assist in the study of subsurface seismic velocity structure. Recent addition of broadband sensors in the local vicinity makes automated detection possible. Such data is available from the United States Geological Survey in Golden-Colorado. A UNIX system was setup to download and decode the seismic data. The Chaos Data Analyzer developed by J. C. Sprott and G. Rowlands at the University of Wisconsin was used to determine the Fractal-Dimension of the decoded data. The development of a fine-tuned Random-Walk algorithm is beginning. In seismic applications, the power-law behavior of the signal properties is common to all seismic zones. However, the magnitude of the Dimension is unique to the particular location of interest. Knowing the fractal dimension contributes to the understanding of the seismic waves as a function of time. This knowledge can then be utilized to calibrate a commercial accelerometer as a safety device in case of seismic activity.

Science Education

Chair: Sufian Forawi

Alford, A.L., and C. A. Schmidt. Department of Biology, Central Missouri State University. ENVIRONMENTAL EDUCATION AT CENTRAL MISSOURI STATE UNIVERSITY: SERVICE AND OUTREACH. Long recognized for providing an excellent post-secondary preparation in the various areas of field biology, the Biology Department at Central Missouri State University is now developing mechanisms for providing environmental education to public school and youth groups in our service area. The initial phase of development includes use of the former Hawksley property (now referred to as the Environmental Education Center; EEC) in Warrensburg. In the Fall of 2001, a major outreach program was delivered. This program was produced by the Mammalogy class at CMSU as a Service Learning project. This event provided 120 second graders with hands-on experience relating to native and endangered mammals of Missouri, bats of Missouri, and field techniques used to study mammals. A second event in the Spring of 2002 and will include coverage of Missouri mammals, birds, herps, insects, fungi and plants. The Missouri Department of Conservation will continue to be involved in facilitating these activities. Plans for an EEC website, and strategies for recruiting funding for further development and expansion of the EEC and its outreach programs at CMSU are presented.

Eckdahl, T.T., R.E. Crumley, and J.C Baker. Department of Biology, Missouri Western State College. RAPD PCR IN THE MICROBIOLOGY LAB: A MOLECULAR APPROACH TO IDENTIFICATION OF BACTERIAL UNKNOWNNS. Standard Microbiology lab manuals provide few activities using modern molecular biology techniques to investigate microorganisms. We developed and implemented the use of Random Amplified Polymorphic DNA PCR in the microbiology student lab as a molecular method for identification of bacterial unknownns. Over the course of three lab periods students worked in groups to perform RAPD PCR on a variety of known and unknown Gram-positive and Gram-negative bacteria. Students learned to set up and perform PCR as well as agarose electrophoresis. More importantly, students spent time analyzing and evaluating experimental data, interpreting electrophoresis band patterns, and identifying unknown bacteria. The two RAPD primers chosen provided good quality band patterns. The distribution of known and unknown species forced students to share data and compare band patterns across gels in order to identify unknownns. This method provided students the opportunity to perform modern molecular techniques in a microbiology lab and allowed opportunity to evaluate and interpret experimental results. From this activity undergraduate students learn the value and application of techniques traditionally performed in genetics courses. We feel this activity is a valuable application of a modern molecular technique and could easily be integrated into any microbiology course to complement traditional bacterial identification methods.

Black, J. Department of Geography, Geology and Planning, Southwest Missouri State University. INTEGRATION OF A SERVICE-LEARNING COMPONENT INTO A PRE-SERVICE TEACHERS' EARTH SCIENCE CONTENT CLASS. An optional one credit hour Citizenship and Service-Learning component was established in 1999 for GRY240 Earth Science for Teachers, a required course for elementary-middle school education majors. Students are introduced to possible community partners, which are external government or service agencies, at the beginning of the semester. They tour a local science museum, where many participants typically work with school groups, prescheduled classes, and the public. At the museum, they may teach in a hands-on laboratory, design science curricula, or work with special events, including community free nights and Earth Day. With other community partners, students may give talks on recycling at schools or teach at local youth organizations. Service learning opportunities reinforce concepts and processes taught in the content classroom and in class field trips, through interpretation of related museum exhibits to the public and the design and teaching of related curricula. It also reinforces abilities associated with a content class requirement of planning and teaching Earth science lesson plans at the university laboratory school. Assessment is based on completion of 40 service hours, recommendation by the community partner, and completion of designated assignments by the instructor.

Carroll, T.M., School of Education and Child Development, Drury University. STRENGTHENING SCIENCE EDUCATION FOR MIDDLE SCHOOL GIRLS IN RURAL SOUTHWEST MISSOURI: TEACHER ASSESSMENT OF PROJECT IMPACT. Opening the Horizon (OTH) is a project sponsored by the National Science Foundation (NSF) aimed at strengthening science education for middle school girls in rural Southwest Missouri. This three-year project involves middle school girls, their parents, teachers, and members of their community, combined with women in science and students from seven local colleges or universities in Southwest Missouri. The teachers involved in the project typically have sole responsibility for their school's science course offerings, and often must do so with a budget of \$100.00 or less. In addition, Southwest Missouri is an area where science is not highly valued, female role models are few, and educating young women in science is a low priority. Hence, the girls involved in the project have limited information available to them about science or science careers. During this first year, OTH has offered these rural female students and their teachers access to cutting-edge science curricular materials, supplies and equipment, normally unaffordable. In addition, a series of workshops have been provided, giving the girls the opportunity to participate in, hands-on, minds-on scientific investigations. These workshops were conducted by women scientists, providing the students with positive role models of women who have succeeded in a variety of science areas. Moreover, participating teachers have been provided training and curriculum resources to enhance their science programs. The participating teachers' assessments of impact of this intervention, in terms of changes in classroom teaching and learning behaviors, increased student interest in scientific endeavors and careers will be discussed.

Dunn, S., D. Lesmeister, and C. A. Schmidt. Department of Biology, Central Missouri State University. MAMMALS OF MISSOURI: SERVICE LEARNING AT CENTRAL MISSOURI STATE UNIVERSITY. Service Learning is one of the four strategic cornerstones upon which Central Missouri State University is building a solid future. The Biology Department at Central Missouri State University is developing mechanisms for providing environmental education to public school and youth groups in our service area. As a Service Learning project, the Fall 2001 class of Mammalogy developed a one-hour program at the Environmental Education Center for two groups of second graders. This program incorporated three stations through which groups of 20-30 students were cycled on a 20-minute rotation. The first addressed native and endangered mammals of Missouri and included pelts (provided by the Missouri Department of Conservation) which the students could handle, as well as taxidermy mounts and museum specimens. The second station was about bat diversity, feeding and habitat requirements, and the use of ultrasonic detectors to study bats based on echolocation signals. This station used live pet bats to give the children a chance to see bats in a non-threatening setting. The third station covered common field techniques used in studying mammals. Students were taught how to set Sherman and Tomahawk live traps, were able to "track" a fluorescently powdered mouse using a UV-light, ran pitfall traps and trapping grids, and had their picture taken by a wildlife camera station. Student and teacher responses were enthusiastically positive.

Frazier, R., C. Meade, T. Moore. Department of Curriculum and Instruction, Central Missouri State University. CHILDREN'S IDEAS, PERSONAL INQUIRY, AND THE EDUCATION OF PRESERVICE ELEMENTARY TEACHERS IN SCIENCE. The many calls for science education reform in the United States suggest that society and individuals benefit from universal scientific literacy. Simultaneously, these calls lament widespread deficiencies in science knowledge among P-12 students and their teachers. An essential reform document, the National Science Education Standards, proposes that, "Inquiry into authentic questions generated from student experiences is the central strategy for teaching science." Our study examines an effort to make inquiry the central strategy of a university science course for preservice teachers (Physics for Teachers). The course design emphasizes firsthand investigation, direct experience with phenomena of interest, children's ideas and thinking in science, concepts from the history of science, and informed comparison with the content of standard modern science. The various perspectives are integrated in a final personal inquiry project. Not only do candidates develop practical and engaging teaching ideas in science, many report increased confidence in their ability to learn and teach science. An important feature of the course rests on the use of children's questions and ideas as starting points for inquiry. For prospective teachers, the projects combine personal curiosity in learning about the world with professional concern for learning about children. Sample projects and postings to an electronic discussion provide our data. Two of the co-authors took the course and will share work and insights in the presentation. We hope to suggest that a genuine orientation toward inquiry among teachers marks a necessary path toward successful reform in science education.

Gordon, A.R. Department of Biomedical Sciences, Southwest Missouri State University. ANALYSIS AND OUTCOMES OF LINKING A COURSE ASSESSMENT TOOL TO SPECIFIC COURSE OBJECTIVES IN AN INTRODUCTORY HUMAN BIOLOGY COURSE. With demands for accountability in education, college instructors are being required to develop assessment tools that measure how well students have achieved course objectives. To assess whether science-oriented and non-science-oriented students were achieving course objectives in a three-course combined lecture, pre-tests and post-tests were developed to assess the meeting of each of the nine lecture course objectives. Data were analyzed and responses were initiated after each semester over a six-year period. Analysis of pre-test results indicated differences in prior knowledge for each of the objectives. This helped focus efforts on those objectives in which prior knowledge was limited and helped explain how the apparent achievement of some objectives consistently ranked higher in post-tests. This specific type of feedback on student learning allowed the instructor to evaluate changes in teaching strategies designed to improve student learning for any particular objective. Although efforts to improve student performance for some objectives show improvement over several semesters, the overall achievement of objectives by students tend to remain the same over the six year period.

Gordon, A.R. Department of Biomedical Sciences, Southwest Missouri State University. IDENTIFICATION, RESPONSES, AND ASSESSMENT OF NEGATIVE ATTITUDES TOWARD SCIENTISTS AND SCIENCE IN A NON-MAJORS HUMAN BIOLOGY COURSE. Attitudes toward scientists and science are solicited during the first week in a scientist-lead discussion hour in an introductory human biology course for non-majors (BMS 100). Most students have negative attitudes that are categorized in ten attitude categories. Categories include character, philosophy, motives of scientists (categories 1-3), influence, relevance, focus, performance, and cost of science (4-8), interest in science (9), and attitude toward the science requirement (10). In a terminal assessment, students report negative to positive attitude changes and are asked to provide an explanation for the change. On the average, 91% of the students now question (24%) or have a positive attitude (67%) for categories 1-8. Only 9% report a continued negative attitude in one or more of the attitude categories. Explanations for changed attitudes include prejudice (range 9-19%), lack of knowledge (range 9-55%), and lack of experience (range 10-65%). Adding elements that address student attitudes toward science and establishing a closer interaction with a practicing scientist in a non-majors course should be equally important as factual content in educating non-science college graduates in an understanding of science.

Gordon, J. Division of Science and Mathematics, Central Methodist College. THE SUCCESSFUL INCORPORATION OF TI-CBL SYSTEMS INTO CHEMISTRY LABORATORIES. The ease of use, relative low cost, and variety of sensors available for the Texas Instruments Calculator-Based Laboratory (TI-CBL) systems has made possible their wide application in the chemistry laboratories at Central Methodist College. The focus of this work is on the particular use of the spectrometer and pressure sensors for kinetic experiments and spectrophotometric titrations. Additional comments will be made on other sensors. The excellent compatibility between the CBLs and "dated" computer systems and the use of Microsoft Excel in data manipulation and presentation will also be discussed.

Kelly, S, T. Jahnke and G. Saunders. Departments of Chemistry and Biology, Southwest Missouri State University. SERVICE LEARNING IN SCIENCE. Although we had experience sending chemistry service-learning students to the Discovery Center of Springfield, a hands-on learning center or to the after school tutoring program at Boys/Girls Clubs of the Ozarks, we had never sent a student into the public schools. We are working on extending our service learning program in chemistry and the other sciences to include Springfield Public Schools (SPS). This project, called the GK-12 Fellowship Program, is funded by the National Science Foundation (NSF) grant # DGE-0086335 (nearly \$1 million for three years). This NSF program supports graduate fellowships and stipends for undergraduate students. The project provides training that enables students in the sciences to serve in K-12 schools as resources knowledgeable about both the content and applications of science, mathematics, engineering, and technology. SMSU science students (GK-12 Fellows) work with SMSU faculty and middle school teachers to make a significant impact on student-teacher contact

and student learning in selected middle school science programs within the SPS system. Although paid positions are wonderful to encourage students to participate in a project, we are investigating several ways to sustain this project and help SPS science teachers. We believe that service-learning is the way to do that, and Dr. Saunders and I will be working to integrate service learning students into our training and program so that we can help more schools and more science teachers. An overview of the SMSU Citizenship and Service Learning program will be presented along with the results of this current project.

Kemp, P., A. Gordon, B. Wing. Departments of Mathematics and Chemistry at Southwest Missouri State University and Department of Biology at Drury University. A PROGRAM TO ENCOURAGE INTEREST OF MIDDLE SCHOOL GIRLS IN SCIENCE AND MATHEMATICS. A three-year grant program called Opening the Horizon is underway in rural southwestern Missouri with the goal of encouraging middle school girls to realize that careers in science and mathematics are achievable goals. Opening the Horizon offers the opportunity for a significant enhancement in the science education of middle school girls in Southwest Missouri. The program seeks to engage up to 200 middle school girls and their science teachers and parents from 26 Ozarks counties as well as school administrators, local and regional communities in an active, self-sustaining program encouraging scientific literacy, curiosity and opportunity. The program is coordinated by a leadership team of women science faculty from SMSU and Drury and the site directors at each of the five regional college and university sites. Hands on science workshops are conducted for the middle school students at local colleges near their homes. The parents and teachers will gradually assume responsibility for planning the workshops. The program also involves women college students majoring in the sciences or math as mentors to the girls. A course is also being offered to the teachers working with the grant on the barriers girls meet in pursuing science and how they can help students to overcome those barriers. The details of this program and its impact thus far will be discussed. Supported by NSF Grant HRD #0002129.

Peery, L., L. Lembke, J. Gordon, S. Harman, and K. Clark. Division of Science and Mathematics, Central Methodist College. TEACHING SCHOLARS PARTNERSHIP PROGRAM, CMC-FAYETTE RIII. The Central Methodist College-Fayette R-III Teaching Partnership which is funded by a NSF grant has brought together five undergraduate Teaching Scholars, members of the Central Methodist science/mathematics faculty, and members of the elementary, middle and secondary faculty from the Fayette public schools. The primary objectives of the CMC-Fayette partnership are to help elementary teachers to broaden the math/science experiences of their students, to help middle school math/science teachers incorporate more hands-on learning, to facilitate laboratory activities for high school science students, and to help all teachers to integrate technology in the classroom. The teaching scholars have developed and supervised a series of laboratory experiences for high school chemistry and physics students and have worked side by side with elementary and middle grade teachers to make science and mathematics instruction more meaningful.

Roy P., D. Beach, N. Mrad, and C. Wolf. School of Education and Child Development, Drury University. IMPACT OF UNIVERSITY PARTNERSHIP IN LEARNING SCIENCE BY HIGH SCHOOL STUDENTS AND THEIR TEACHER'S PERSPECTIVE. A Developmental School Partnership among Central High School, Pipkin Middle School, Boyd/Berry Elementary School and Drury University, formed in 1995 in collaboration with Yale University, has already resulted in significant improvements in each of the member schools and the professional education program of Drury University. A grant was received from the Council of Independent Colleges supported by the National Science Foundation to enhance mathematics and science literacy among public school students. Five undergraduate science majors from Drury University, four science and mathematics faculty members, and two science educators have been involved in this project. Five undergraduate students, known as "Teaching Scholars," taught science concepts related to the MAP test. High school students were involved in conducting research leading to entries in the Southwest District Science Fair. The results of this project, in terms of students' attitude, laboratory skills, achievements, development of self-confidence, cooperative team-work, increase of scientific knowledge, and interest in science related careers, will be discussed. The outcome of this project will be presented by a Drury University "Teaching Scholar", a public school faculty member, and a student from Central High School. A science teacher's perspective of the relationship between Science Fair and the MAP test will be discussed.

Roy P., J. Detwiler, A. Cox, and T. Reigel. School of Education and Child Development, Drury University. MIDDLE SCHOOL STUDENT'S EXPERIENCE IN MAKING SCIENCE FAIR WITH UNIVERSITY "TEACHING SCHOLAR". Every spring, public school students throughout the nation are involved in making science fair projects. Science educators claim that students learn scientific methods, process skills, and science concepts through these inquiry based research projects. Science teachers can cover some of the state and national standards through different hands-on science fair projects. This is an added benefit for science teachers. Middle school students from an inner city public school were involved in collaborative research projects with Drury University "Teaching Scholars" leading to science fair. Some of these practical projects include: a) Water quality analysis of Wilson's Creek and its effects on biodiversity, b) How can we prevent the weathering of our sidewalks and driveways? and c) Which antibacterial cleanser kills the most bacteria? The research projects were supported by the mathematics and science faculty mentors of Drury University. The laboratory facilities of the university were used by public school students. Public school science teachers actively participated in this joint venture. The description of the student's hands-on projects as well as the results of these projects will be presented and shared by a Drury "Teaching Scholar", a public school science teacher and a public school student. This project was supported by a grant from the Council of Independent Colleges.

Schultheiss, N., J. Erickson, T. Garson, Kathy Shade, G. Saunders, and T. Jahnke. Departments of Chemistry and Biology, Southwest Missouri State University. SCIENCE MAJORS IN MIDDLE SCHOOLS? – STOCKROOM ORGANIZATION, SAFETY AND WASTE DISPOSAL. SMSU science students (seniors and graduate students) have been working in four Springfield middle schools during this past year. SMSU students (GK-12 Fellows) work with SMSU faculty and middle school teachers to make a significant impact on student-teacher contact and student learning. In addition, because we have the resources and the time, the GK-12 Fellows were first assigned to clean and organize middle school science supply rooms. These tasks are often on the to-do list for a teacher but rarely do they have the time and the chemistry knowledge to store and dispose of chemicals properly. In each case the contents of the room was inventoried, an MSDS was found for each chemical that would remain, a folder with all MSDS's was prepared, and the excess or unwanted chemicals were sent for disposal. Questions were referred to SMSU faculty consultants helping with the grant. Logistics and how you can help your local school district will be presented. This project is funded by the GK-12 Fellowship Program, NSF grant # DGE-0086335.

Shearer, J. and K. Manivannan. Department of Physics, Astronomy, and Materials Science, Southwest Missouri State University. EVALUATION OF AN EXTRACURRICULAR SCIENCE ENRICHMENT PROGRAM FOR ELEMENTARY SCHOOL STUDENTS. The purpose of this study is to evaluate the effectiveness of an after school science enrichment program at the Discovery Center of Missouri, an interactive science museum in Springfield, Missouri. More than 100 students in grades 2-5 attended this program for 8-10 hours over a period of eight weeks. At the Center, using an electronic audience response system, we administered an assessment designed to elicit common misconceptions about the physical world. Post-test results showed a content knowledge improvement of 67%. In another pre- and post- test series designed at the Center to probe student's views of science, students were given two minutes to list words they would associate with science. Post-test results showed a more than 20% improvement in students' perception of science as a discipline. Analysis of students' science grades and attendance at school for a period of one year before and after the program appears to be inconclusive, and currently we are collecting additional data to investigate this. Overall, our study suggests that a *minimal* investment in an after school science enrichment program can help improve elementary school children's performance in science. Supported in part by "Preparing Tomorrow's Teachers to Use Technology," United States Department of Education grant #P342A990411.

White, A., C. Koenig, J. Bayless, H. Neill, K. Shade, G. Saunders, and T. Jahnke. Departments of Biology, Chemistry, and Geography, Geology, and Planning, Southwest Missouri State University. SCIENCE MAJORS IN MIDDLE SCHOOLS? – MORE TECHNOLOGY AND LAB WORK. SMSU science students (seniors and graduate students) have been working in four Springfield middle schools during this past year. SMSU students (GK-12 Fellows) work with SMSU faculty and middle school teachers to make a significant impact

on student-teacher contact and student learning. The GK-12 Fellows have set up science displays, painted murals, prepped labs, conducted labs with teachers and students, and helped individual students. The SMSU students have shared their research projects with the teachers and students in their schools – everything from bringing bats to class to talking about why their research in chemistry or material science is significant. They are also preparing groups of students for science fair projects and Science Olympiad. An overview of the program as well as evaluations of principals, teachers, students and fellows will be presented. Our website also gives information about current projects: <http://www.gk-12fellows.smsu.edu/> The project is funded by the GK-12 Fellowship Program, NSF grant # DGE-0086335.

Speleology

Chair: David C. Ashley

Ashley, D. C.,¹ P. McKenzie,² and T. Aley.³ **1 Department of Biology, Missouri Western State College, 2 Ecological Services, U.S. Fish and Wildlife Service and 3 Ozark Underground Laboratory.** POPULATION STATUS OF THE TUMBLING CREEK CAVESNAIL (HYDROBIIDAE: *ANTROBIA CULVERI*). The Tumbling Creek Cavesnail was described in 1971 based on specimens recovered from Tumbling Creek Cave (TCC) in Taney County, Missouri. No specimens of this species have ever been found in any other cave. A stratified sampling scheme was developed in 1996 to monitor the population of this endemic snail. This report details the results of this monitoring study. Snail populations within the transect area in Tumbling Creek Cave have decreased substantially since 1996. No specimens of *A. culveri* have been seen in the transect area during five successive trips (between Jan 2001 and August, 2001). Populations of several stream crustaceans have remained relatively stable during the course of the study. A freshwater limpet (*Ferrissia* sp.) experienced a remarkable population increase during the summer of 2001. An isolated population of specimens was found in a region of the cave upstream of the transect area. This study was funded in part by the U.S. Fish And Wildlife Service.

Ashley, D. C. **Department of Biology, Missouri Western State College.** PRELIMINARY STUDIES ON THE NATURAL HISTORY OF AN EPIGEAN CRAYFISH IN TUMBLING CREEK CAVE. I have been studying a population of the Ringed Crayfish (*Orconectes neglectus*) in Tumbling Creek Cave (TCC), Taney County, Missouri, since February of 2001. These studies have been conducted in conjunction with my trips to TCC to monitor the endemic Tumbling Creek Cavesnail (*Antrobia culveri*). During each trip to the cave, I deploy ten traps (modified YellowJacket Traps) within the cave stream. Traps are baited with a portion of chicken wing and examined after a minimum of 10 hours. All crayfish within the traps are measured, weighed and sexed before being released. Five visits to the same stream transect area within the cave have yielded from 8 to 44 crayfish specimens. I have recorded data on 124 specimens thus far. Starting with the most recent visit to the cave, I began marking specimens permanently using a sequentially numbered visible implant tag (Northwest Marine Technologies). This will provide the opportu-

nity to assess movement patterns of individuals and to estimate crayfish populations using Lincoln Peterson calculations. This study was funded in part by the U.S. Fish And Wildlife Service.

Elliott, W.R. **Natural History Division, Missouri Department of Conservation.** THE ZOOGEOGRAPHY AND BIODIVERSITY OF MISSOURI CAVES. The Missouri Biospeleological Database (MBD) was developed to track and analyze Missouri's rich cave fauna. About 800 (14%) of 5,700 caves have biological records, but only 309 (5%) are adequately documented. There are about 67 troglobites (including 40 aquatic species or "styglobites"), 141 troglaphiles (12 aquatic), 203 troglonexes (20 aquatic), 249 accidentals (12 aquatic), and 184 species of uncertain ecology (105 aquatic). In comparison, caves east of the Mississippi River contain a higher diversity of terrestrial troglobites. Troglobites were reported from 390 Missouri sites, but 21 troglobites occur at single sites. Nine undescribed troglobites are tracked. Karst zoogeographic regions include the Springfield and Salem plateaus, Ozark River Basins, Perryville Karst, and isolated areas, such as Caney Mountain. I defined endemism as one divided by the number of known sites for each species. "Site endemism" (SE) is the sum of troglobite endemism scores within a site. Caves were ranked according to a biodiversity score calculated as the product of the total number of species, number of troglobites and SE. The richest, most diverse cave is Tumbling Creek Cave, Taney County, with 109 total species, 9 troglobites, SE of 4.0050 and a biodiversity score 3929. Mystery Cave, Perry County, is ranked second with 51 species, 8 troglobites, SE of 1.5237, and a biodiversity score of 622. A ranked list of caves was derived for conservation planning. Many species and biologically important caves will be added to the

Ireland, Lawrence and Elliott, W.R. **Natural History Division, Missouri Department of Conservation.** THE MISSOURI CAVE LIFE SURVEY - RESULTS FROM 22 CAVES. Caves are important habitats for many obligate and non-obligate species, though little is known about the status of their fauna. The Missouri Department of Conservation (MDC) surveyed cave animals in 436 caves from 1978 through 1984. The Missouri Caves and Karst Conservancy (MCKC) is now working with the MDC to revisit a geographically widespread selection of at least 40 of the more diverse caves to recount vertebrate populations. Visiting each site within two weeks of the original study's date, volunteers count animals, collect water samples and temperature data, and assess the condition of each cave. Preliminary data from 22 caves are presented, and show an overall decline for most species, though frog and gray bat (*Myotis grisescens*) numbers have increased. Human impact and drought conditions are considered to have a negative impact on most of the subjects. Results from this study's final report will be used for making land management decisions regarding cave communities.

Collegiate Division

2002

Social and Behavioral Sciences

Pfenenger, A.L. and K.A. DeBord. Division of Social and Behavioral Sciences, Lincoln University. EFFECTS OF AN EDUCATIONAL INTERVENTION ON COLOR-BLIND RACIAL ATTITUDES. The current study examined a unique component of racial attitudes called color-blindness. A person high in color-blindness refuses to see the role race plays in everyday social interactions and how that role can dramatically affect outcomes regarding social justice. Previous studies (Neville, Lilly, Duran, Lee, Browne, 2000; Rowden & DeBord, 2000) have shown that sensitivity seminars and classes devoted to diversity can effectively decrease the degree to which a person adopts color-blind attitudes. We wanted to know whether interspersing lectures on race-related issues throughout a semester of general psychology would have a similar effect on students' attitudes. The Color-Blind Racial Attitudes Scale (CoBRAS; Neville, et al., 2000) was completed by 26 students at the beginning and end of a semester of general psychology. These students were intermittently presented with lecture material on racial issues throughout the semester. An additional 80 students enrolled in other sections of general psychology also completed the CoBRAS at the end of the same semester. Analyses revealed that the students in the race-relevant general psychology class did not significantly change their attitudes, $t(23) = 1.57$, $p = .13$, nor did they differ from students who were not presented with the material, $t(88) = 0.64$, $p = .53$. Additional analyses indicated that students did not prefer the race-related lectures over other lectures, $t(23) = 1.21$, $p > .05$, but they did prefer presentations that included videos, $t(23) = 5.00$, $p < .05$. Our results imply that educational interventions aimed at changing racial attitudes need to be intensive and consistent to be effective.

Biology Section

Aubrey, Douglas P., and D. Alexander Wait. NEED SCHOOL@@@ FIRE EFFECTS ON SEEDLING AND SAPLING COMPOSITION IN AN OZARK FOREST: A DEMOGRAPHIC AND PHYSIOLOGICAL APPROACH. Understanding species and community level responses of seedlings and saplings to fire management is important in determining the effectiveness of habitat restoration. We have initiated a long-term demographic and physiological investigation into the effects of fire on the composition of seedlings and saplings of the dominant overstory trees, Oak (*Quercus*), Hickory (*Carya*), and Cedar (*Juniperus*) within the Drury-Mincy Conservation Area in Taney County, Missouri. The Missouri Department of Conservation has implemented controlled burns for the purpose of savanna restoration in this area. We are sampling in three different habitat types; unburned closed forest, recently burned

closed forest, and regularly burned glade/savanna. All target species within a 308m² plot/habitat were tagged and height, basal area, and dominance determined. Leaf photosynthetic rates and nitrogen (N) were collected, and habitat leaf area index (LAI) was determined. Demographic results indicated that total density was greatest in the glade/savanna habitats compared to either the burned or unburned closed forest habitats, with White Oaks dominating the glade/savanna habitat and Red Oaks dominating both closed forest habitats. Total density was similar in the burned closed forest and the unburned closed forest. Photosynthetic rates for all species were highest in glade/savanna habitats, which also had the lowest LAI and highest total leaf N. White Oak had the highest photosynthetic rates, followed by Hickory and Red Oak; however, Red Oak had the highest leaf N. In total, these results indicate only very subtle effects of recent burning on saplings and seedlings in closed Ozark forests.

Beale, A. William Jewell College. *Caedibacter taeniospiralis*, an endosymbiotic bacterium that lives inside *Paramecia tetraurelia*, produces an R body and a toxin. The R body encoding locus, or *reb* locus, has been cloned into *E. coli*. Although the R body protein is expressed, no toxic activity has been detected. The *reb* locus contains 4 open reading frames: *reb A*, *reb B*, *reb C*, and *reb D*. However, protein expression assays did not detect expression of the *reb D* protein, even though the *reb D* open reading frame appears to encode a functional gene. The analysis of the putative amino acid sequences showed a close homology between the four polypeptides. To determine why the *reb D* gene was not being expressed, sequence analysis upstream of the open reading frame was performed, and a potential catabolite repressor sequence was identified. This has led to the hypothesis that *reb D* is a highly regulated gene and may encode the toxin. We constructed two deletion derivatives of the *reb* locus to determine the function of *reb D*. Using over-lap extension PCR we have generated pBQ88 Δ CRS, that lacks the catabolite regulatory sequence, and pBQ88 Δ *rebD*, that is missing the entire *rebD* open reading frame. We will now use RT-PCR to measure gene expression in these clones prior to the performance of killing tests.

Coleman, M. and L. Wetmore William Jewell College EXPRESSION OF CYCLIN B1 IN U373 GLIOBLASTOMA MULTIFORME CELLS. Cyclin B1 is an intracellular protein that is involved in the G₂/M cell cycle transition, controlling cell division. This G₂/M transition is inhibited by DNA damage. Glioblastoma multiforme is one of the most invasive and aggressive forms of brain tumor, and makes up 45% of all brain tumors. In this experiment the expression of cyclin B1 is examined in U373 glioblastoma multiforme cells by treating the cells with one or more of the following chemotherapeutic agents: etoposide (VP-16), genistein, and caffeine. VP-16 and genistein, both topoisomerase II inhibitors, activate apoptosis (programmed cell death) pathways. Caffeine overrides the G₂/M checkpoint of the cell cycle and forces the cells with DNA damage to continue into

mitosis (cell division). A testable hypothesis is in the presence of VP-16, genistein, and caffeine, cyclin B1 expression in U373 cells will increase. Immunohistochemistry, an antibody reaction, is used to determine the expression of cyclin B1 within the cell. A pink-colored product appears in the cell, where cyclin B1 is located. Cells are then examined for the intensity of cyclin B1 expression using a microscopy.

Cooper, S.,¹ R. Kupfer¹, B. Neil¹, L. Shimkets², and K. Lee¹
¹Division of Science (Biology), Truman State. ²Department of Microbiology, University of Georgia University. CHARACTERIZATION OF THE PUTATIVE ZINC METALLOPROTEASE, *prt1*, IN *MYXOCOCCUS XANTHUS* BY GENE DISRUPTION. Zinc metalloproteases have been implicated in the production of extracellular matrix that plays a significant role in biofilm formation. Recently finished *M. xanthus* genome sequencing data revealed presence of five putative zinc metalloproteases. The internal fragment of one of them, *prt1*, was amplified, cloned into a vector, and introduced into the wild type and two different motility mutants to disrupt *prt1* through a single homologous recombination event. The effect of *prt1* disruption on the extracellular matrix production, cohesion, and development is under investigation with final data to be presented at the research symposium. Cohesion assays have demonstrated a fifty percent increase within *prt1* mutants with respect to the wild type. Development is also affected with current data pointing toward a fifty percent reduction in spore formation.

Davis, H.K. and D.P. Heruth. Department of Biology, William Jewell College. ISOLATION AND CHARACTERIZATION OF A DRUG RESISTANT COLON CARCINOMA CELL LINE. Previous studies by our research group determined that a de-differentiated cell line, SW837-DH2, exhibited minimal decreased c-myc levels when exposed to sodium butyrate. However, when treated with genistein, a tyrosine kinase inhibitor versus a histone deacetylase inhibitor, a dramatic reduction in myc levels resulted. This suggests an alternate form of drug resistance than the "Multidrug resistant" phenotype found in many types of metastatic cancers. With treatment of 2 mM Sodium Butyrate daily, a de-differentiated SW837 cell line has been developed similar to the SW837-DH2 cell line. This de-differentiated cell line exhibits an altered morphology with pseudopod extensions. In addition, under microscopy an increase in fluorescent granules is noted indicating a rise in mitochondrial activity. Currently, experiments are underway to produce a pure clone of the de-differentiated cell line and to test whether this resistance is synonymous to histone deacetylase inhibitors as expected or follows a more common "multidrug resistant" phenotype.

Dunn, L., M.F., and S. Vortriede. Haskins Department of Biology, Rockhurst University. A TWO-YEAR STUDY OF BLISTER BEETLE (MELOIDAE) OCCURRENCE AND BEHAVIOR IN WESTERN MISSOURI AND EASTERN KANSAS ALFALFA FIELDS. Eleven fields, totaling approximately 57 hectares (140 acres), of alfalfa in Jackson and Johnson Counties, MO and Franklin County, KS were sampled weekly between June-September 2000 and 2001. Walking a randomly-generated grid, investigators alternated sweeping with visual

inspections. No correlations were found between field size and the following variables: number of blister beetle swarms, population size of the swarms, and total number of beetles observed in each field. Mark-recapture studies, which produced only a few recaptured individuals, indicated some beetles tended to remain for several weeks in the initial area of capture. Global positioning system data were used to record locations of swarms and their dispersal patterns within fields. Other data recorded included: weather, status of alfalfa development, and types of plant damage, if any. In four of the alfalfa fields, general insect samples were obtained weekly by collecting all insects from five randomly-selected sweep samples and preserved for later analysis.

Englert, V.D.,¹ R.L. Maser,² J.A. Dilts,¹ and D.P. Heruth Daniel P.¹ ¹Department of Biology, William Jewell College. ²University of Kansas Medical Center. ISOLATION AND CHARACTERIZATION OF THE *REB* LOCUS FROM *PSEUDOMONAS TAENIOSPIRALIS*. *Pseudomonas taeniospiralis*, a hydrogen-oxidizing, gram-negative soil bacterium, produce large protein ribbons, termed R bodies. R bodies are coiled into cylindrical structures within bacterial cells and have been found in both free-living bacteria within the *Pseudomonas* genus and endosymbiotic bacteria within the *Caedibacter* genus. Five types of R-bodies have been characterized (types 51, 7, Cc, Pt, and Pa) based on physical dimensions, morphology, and behavior in chemical environments. The genetic determinants, *reb* locus, for type 51 R-body production in *C. taeniospiralis* have been determined previously and we have demonstrated that the *rebB* genes from both *C. taeniospiralis* and *P. taeniospiralis* are identical. In this study we utilized the known similarities between the two *rebB* genes to clone and sequence the complete *P. taeniospiralis* type Pt *reb* locus. Comparison of the two *reb* loci allows for a better understanding of the evolutionary relationship between these two types of R bodies.

Fairchild, S.N. and T.J. Allen. Department of Biology, William Jewell College. COMPARISON OF TWO FILTRATION SYSTEMS IN THE REMOVAL OF *CRYPTOSPORIDIUM PARVUM* AND *GIARDIA LAMBLIA*. Only about one-third of the people in the world's least developed countries have dependable access to a safe water supply and adequate sanitary facilities. There are two solutions to this problem. The first is education and the other is an effective water filtration. The latter solution should have a low construction cost, can be easily maintained, and that utilizes native materials. David Manz created a filtration system that uses sand to filter out the impurities in water, however, this system is used primarily for towns and cities; therefore, it is difficult for people to make multiple trips a day just for clean water. The people avoid making the trips and sacrifice themselves by using contaminated water. Smaller scaled versions of Manz's filter have been constructed. The purpose of the study is to compare Manz's system set up (gravel and sand only) to another system with additional sand layering. The efficacy of the two filters' set up will be determined quantitatively and by the ability to remove *Cryptosporidium* and *Giardia lamblia* from sampled water. My hypothesis is that the new set up will not only induce better filtration capabilities but also enable a wide distribution of the system to families rather than to only communities. Water samples will be taken from

Rush Creek in Liberty, Missouri, two times a day (A.M. and P.M.). Twelve samples per week will be analyzed. Temperatures and counts of *Cryptosporidium* and *Giardia lamblia* before and after will be recorded.

Fongué, V., G. O'Conner¹, and D. Gibbs.² ¹Biology Department and ²Chemistry Department, Rockhurst University. THE FEEDING DETERRENT EFFECT OF PHLOXINE-B AND OTHER LIGHT ACTIVATED COMPOUNDS ON LARVAE OF *TENEbrio MOLITOR*. Previous bioassays showed that plant extracts from the class of terpenes are good feeding deterrents for insects that normally feed on stored grain products or live plants. The present bioassays were conducted on the class of compound called Chromosomes. We attempted to ascertain the effects of anthraquinone and its sodium salt, Phloxine-B, erythrocin-B, fluorencein, 4-phenylazofluorescein, juglone and Phloxine-B associated to an azo group. Each chemical was tested at concentrations varying between 200 ppm and 800 ppm. Insects were placed in glass bowls with 50 g of Carolina Biological Bran Meal, for culturing mealworms. One group was exposed to the sunlight and the other was continuously kept in the dark. At concentrations as low as 200 ppm, Phloxine-B showed some killing activity, which increased with its concentration. The other Photosensitizers showed some killing activity, but with a less intensity. The addition of an azo group to anthraquinone increases its photo-activity. In the group exposed to light, a maximum of 90% of the insects died while in the group kept in the dark a maximum of 10% died. In each control group, no more than 10% died. Results suggest that photo-activated compounds such as Phloxine-B or anthraquinone may be used as feeding deterrents at very low concentrations.

Graham, J.M. and T.J. Allen, Department of Biology, William Jewell College and CVOR St. John's Regional Hospital. ENDOVASCULAR VERSUS OPEN REPAIR OF ABDOMINAL AORTIC ANEURYSMS: A SINGLE-CENTER STUDY. Aortic abdominal aneurysms (AAAs) represent a degenerative process and are characterized by a bulge in the arteriole wall. Given their propensity to rupture, AAAs pose a significant health care problem. The conventional method of repairing AAAs involves a large abdominal incision. However, there is a new method that removes the need of this incision and the resulting complications. This new method has made it possible to replace the defective artery with an artificial one called an endograft via two small incisions in the groin. Much controversy exists as to the feasibility of this new method. To address this question, a matched-pair analysis on the outcomes of the two methods was conducted. In the first year of an endografting program, 62 patients underwent endovascular therapy for the treatment of AAA. Data collected was then retrospectively compared to a matched group of 55 patients undergoing open repair. Patients treated by the conventional method had significantly higher blood loss, mean operative time, and hospital stay. However, complication rates and incidence of reoperation were significantly higher in the patients treated with an endograft. While there are obvious advantages to endovascular treatment of AAAs, individual risk factors should be considered in deciding which procedure to employ.

Hirschman, M., S. Addison, T. Randall, S. Recker, K. McConkey, S. Tye, and R. Enochs, Department of Science, Central Methodist College. EFFECT OF STRESS AND HOUSING ON IgM RESPONSE TO IMMUNE CHALLENGE BY LIPOPOLYSACCHARIDE (LPS) IN RATS. Numerous studies have indicated that immune function is influenced by stress as well as social support. The effect may vary under acute versus chronic stress conditions. This study was designed to investigate both the effects of an acute stress, as well as group versus individual housing on production of IgM following injection of LPS. Two groups of rats were housed individually and two groups were in groups of four. Each rat was injected with 100 ug/kg LPS at 8 am. Fifteen minutes later stressed rats were subjected to an eight-minute forced swim at 15°C. Tail vein blood was drawn every 24 hrs for 4 days and then every other day until 20 days after injection. Blood was refrigerated for 24 hrs then the serum collected and frozen until assay. Total serum IgM was determined by performing an Enzyme-Linked Immunosorbent Assay (ELISA). Preliminary results indicated that both individually housed and group housed unstressed rats showed elevated levels of total IgM between three and twelve days after injection of LPS. This increase was greater in the group which was housed individually. Rats which were subjected to cold swim stress after LPS injection failed to show a consistent increase in IgM response whether housed individually or in groups. While these results are preliminary they do suggest that acute stress has a negative impact on the ability to respond to immune challenge. The results suggest that housing differences may also have some effect. Additional studies of LPS specific IgM level should help elucidate the nature of this response.

Johnson, A.L.,¹ R. L. Maser², J. A. Dilts¹, and D.P. Heruth¹, ¹Department of Biology, William Jewell College. ²University of Kansas Medical Center. ISOLATION AND CHARACTERIZATION OF THE *CAEDIBACTER TAENIOSPIRALIS* PLASMID, PKAP116. *Paramecium tetraurelia* 116 contain *Caedibacter taeniospiralis*, bacterial endosymbionts that demonstrate killing activity towards *Paramecium* without endosymbionts. *Caedibacter* maintain a 43 kb plasmid (pKAP116) and produce rolled proteins called refractile bodies or R bodies. R bodies are associated with killing activity and are coded for by the *reb* locus, a 1931 bp region on the plasmid. Of the four closely related *reb* locus genes, two encode for R bodies, one allows for post-translational modification of these genes, and the fourth is thought to encode for the killing toxin. pKAP116 has been isolated from *Caedibacter*, modified by insertion of a kan^R *Mu* transposon *in vitro*, and transformed by electroporation into *E. coli*. The *E. coli* transformants produce R bodies. DNA sequence analysis of the plasmid is possible by using sequencing primers located at both ends of the transposon. Here we report the characterization of the potential open reading frames (ORFs), consisting of both ORFs with homologies to known genes and newly identified ORFS. Analysis of these sequences provides an understanding of (1) the evolution of the plasmid, (2) the genes necessary for killing, and (3) the endosymbiotic relationship between *C. taeniospiralis* and *P. tetraurelia* 116.

***Kupfer, R., B. Hughes, and K. Lee. Department of Biology, Truman State University.** EFFECTS OF LIGHT EXPOSURE ON *MYXOCOCCUS XANTHUS* DEVELOPMENT. Previous studies have demonstrated that exposure to light during development impedes *M. xanthus* fruiting body formation by an unknown mechanism. This study was conducted to determine the effects of varying intensities and durations of light exposure in order to gain more knowledge of the inhibition process. Cells at mid-exponential phase of growth were harvested and spotted on TPM non-nutrient agar to induce sporulation. To examine the effects of light exposure time, samples were incubated at 32°C under light conditions and placed in subsequent dark conditions at increments of 0 (control), 3, 6, 12, 24, 48, 96, and 144 hours. Fruiting body formation under natural light conditions was studied in a greenhouse by incubating samples in complete darkness (control), semi-shade, and direct sunlight. In both phases of the experiment, inhibitive effects were quantified by conducting a spore count using a Petroff-Hausser counting chamber under a phase contrast microscope. *M. xanthus* spore development exhibited a significant quantitative decline as light exposure time was increased over the entire 144-hour period ($p < 0.0001$), particularly between the 24-hour and 48-hour exposure times. Development was also inhibited in cultures incubated under direct sunlight ($p = 0.013$) as well as in semi-shade ($p = 0.011$) compared to the control. The results of this study suggest that inhibition of development is directly proportional to duration and intensity of light exposure, and that the critical stage of development most afflicted by light occurs 24 to 48 hours after starvation.

Marquardt, S. R. and C.A. Schmidt. Department of Biology, Central Missouri State University. CORRELATES OF URBANIZATION AND USE OF URBAN HABITAT BY BATS. Urban development often results in a reduction of natural areas, an increase in the number of artificial light sources, an increase in human population density that results in more man-made structures, and expansion in total area as well as changes in the general shape of the city. It is important to determine how urbanization and human activity impact bat communities because bats are sensitive indicators of ecosystem health. The goal of this study is to examine the relationship between urbanization factors and bat activity within urban areas. Seven cities in Missouri were chosen as sampling locations based on population size and general shape. A total of eight monitoring sites (outer zone: sites 1-4; inner zone: sites 5-8) were selected in a circular pattern within each city. Using broad-band ultrasound detectors two research teams recorded the number of bat passes observed at each site. The total number of bat passes and the number of passes in each sampling zone was regressed against six urbanization factors. Of the factors considered in this study, the strongest associations were between the number of passes in the outer zone and both percentage of agricultural land (positive association) and percentage of forested land (negative association). These associations suggest that even though streetlights may provide concentrations of prey species, bats still use forested areas extensively to forage. Under this scenario, as agricultural land replaces suitable forest habitat, bats would shift some of their foraging activity to the clusters of insects attracted to the city lights.

Meler J. William Jewell College FATTY ACID INDUCED APOPTOSIS IN VASCULAR SMOOTH MUSCLE CELLS (VSMCS). Palmitate (C16:0) and oleate (C18:1) are the most concentrated fatty acids in blood plasma and serve in such cellular functions as metabolism, intracellular signaling molecules, and cell membrane formation. In addition, certain saturated fatty acids, such as palmitate, have been implicated in cellular apoptosis (programmed cell death) of many cell types including cardiac myocytes and granulosa cells. This data suggests the possibility that other cell types may apoptose along similar pathways. The purpose of this study is to observe VSMCs exposed to palmitate and oleate to determine whether saturated fatty acids induce apoptosis in VSMCs. VSMCs have a contractile role *in vivo*, and are the primary component of blood vessel walls where they mediate changes in and maintenance of blood pressure. In addition, VSMCs in a synthetic state are found in atherosclerotic plaque, and therefore may be implicated in plaque destabilization, rupture, and thrombosis once apoptosed. To determine whether fatty acids induce apoptosis in VSMCs, cultured VSMCs (which resemble synthetic VSMCs *in vivo*) will be exposed to palmitate and oleate (0.5 mM each) for 24 hours, after which the extent of apoptosis will be determined by flow cytometry. It is hypothesized that palmitate will induce apoptosis while oleate will not.

Mompati, F., and M. F. Haskins, Department of Biology, Rockhurst University. OCCURRENCE OF PENTATOMIDAE IN ALFALFA FROM WESTERN MISSOURI AND EASTERN KANSAS. During the summers of 2000 and 2001 insects were collected from alfalfa fields located in Johnson and Jackson Counties in Missouri, and Franklin County, Kansas. Sweep nets were used to sample the fields on a weekly basis between June and September of each year. Captured stink bugs were classified into two genera. Although stink bugs have piercing-sucking mouthparts which enable them to feed on plants, the population sizes of stink bugs in alfalfa is typically low, as supported by our data, and the insects are not considered a major threat to alfalfa.

Myers, J.L., and M.C. Barnhart. Department of Biology, Southwest Missouri State University. EFFECTS OF HYPOXIA ON SURVIVORSHIP AND GROWTH OF JUVENILE MUSSELS. Native freshwater mussels (Unionidae) are the most threatened family of animals in North America. This investigation explores low oxygen (hypoxia) as a possible threat to the survivorship of juvenile mussels less than one month old. Juveniles of *Lampsilis rafinesqueana*, *L. reeveiana*, and *L. cardium* were subjected to dissolved oxygen (DO) levels between 4% and 85% of air saturation (AS). In each experiment, 4 replicate groups of 5-6 juveniles were placed into each of 6 DO levels at 20°C. The number of surviving juveniles was recorded at 2-day intervals. Time to 50% mortality (LT_{50}) was determined for each treatment group. LT_{50} ranged from 7-33 days and varied among species and DO treatments. LT_{50} declined significantly below about 10% AS (1 mg/L) in 3 of 4 species. In contrast, LT_{50} of *L. cardium* increased below 10% AS. Growth was not affected by DO. The results indicate that juvenile *Lampsilis* are highly tolerant of low levels of dissolved oxygen. However, this study did not consider other factors, such as CO₂ and pH, which vary with DO in field conditions. This study was supported by funding from the U.S. Fish and Wildlife Service and the Missouri Department of Conservation.

Pittman, A., K. Baumgartner, L.A. Wetmore, and D.P. Heruth. Departments of Biology and Chemistry, William Jewell College. GENISTEIN-INDUCED APOPTOSIS IN HCT8 COLON CARCINOMA CELLS Our research has been directed toward an understanding of how the *c-myc* oncogene is regulated in cells of the colorectal mucosa. In previous work we have found that genistein, a tyrosine kinase inhibitor, caused a dramatic decrease in the abundance of *c-myc* RNA and an inhibition of proliferation in the HCT8 colon carcinoma cells. In the present work we demonstrate that genistein induces apoptosis in HCT8 cells. Apoptosis was determined by flow cytometry to measure the sub G1 population, microscopy with ethidium bromide/acridine orange staining to visualize nuclear condensation, and identification of DNA fragmentation by gel electrophoresis. Treatment of HCT8 cells with 60 ug/ml resulted in a 3-, 11-, and 4.5-fold increase at 24, 48, and 72 hours, respectively, compared with untreated cells. To understand further the role of the *c-myc* pathway and to potentially identify additional genes involved in the apoptotic response to genistein, we performed DNA microarray assays to measure differential gene expression between treated and untreated HCT8 cells. We report here a profile of genes with at least a two-fold gene difference in gene expression.

Schumacher, S.A.,¹ K.A. McCullough,¹ R. Maser,² J.A. Dilts,¹ and D.P. Heruth.¹ Department of Biology, William Jewell College. ISOLATION AND CHARACTERIZATION OF A *RECQ* DNA HELICASE FROM *TETRAHYMENA THERMOPHILA*. Aging occurs in nearly all organisms, yet the exact cause for aging remains unknown. However, the discovery of genes that, when mutated, cause premature aging conditions in humans (*WRN*, *BLM*) and yeast (*Sgs1*) has provided model systems for understanding the aging process. These genes encode a specific class of proteins, *RecQ* DNA helicases, that are involved in the maintenance of DNA. Due to the complexity of higher organisms, less complex organisms provide useful model systems to try to identify key molecular components and their functions within the aging process. We have chosen to study the aging process in *Tetrahymena thermophila*, a ciliated protozoan, because, unlike most organisms, it has an unlimited clonal lifespan. Therefore, we hypothesized that the *RecQ* helicase from *T. thermophila* may provide insight into mechanisms that control clonal lifespan. We report here that we have cloned a *RecQ* DNA helicase from *T. thermophila* that is similar to yeast *Sgs1* and human *WRN* and *BLM*. We will now be able to complete functional assays on the *Tetrahymena* protein that will help us to understand further the aging process in all organisms.

Sesser, L.M. and A. R. Oller, Ph.D. Department of Biology and Earth Science, Central Missouri State University. MANGANESE II AND ULTRAVIOLET RADIATION EFFECTS ON *PROTEUS MIRABILIS* ATCC 7002. *Deinococcus radiodurans* is a bacterium that has the capability of resisting high levels of ultraviolet (UV) radiation. *Proteus mirabilis* is also considered highly resistant to UV radiation. According to Chou and Tan (1990), manganese II can cause abnormal spurts of cell growth after the normal log phase, referred to as Mn(II)-induced cell division (Mn-CD) in *D. radiodurans*. Thus far, other bacterial species tested for the Mn-CD growth do not exhibit a resistance to UV radiation. This study

tested *P. mirabilis* ATCC 7002 to determine if Mn-CD growth phase can be induced in another bacterial genus upon exposure to manganese, as well as if manganese causes susceptibility changes to UV or antibiotics. Manganese II was added to 250 mL flasks and samples were taken every two hours to perform plate counts, to prepare slides for microscopy, and to determine growth spectrophotometrically. Rifampicin and norfloxacin-laden plates were subjected to UV irradiation and growth was measured. Control groups were similarly performed and all experiments were performed in duplicate. Results suggest that manganese has a significant effect on the number of *P. mirabilis* cells in relation to the control group. Manganese also appeared to cause *P. mirabilis* to become more sensitive to UV radiation. This study was supported by the McNair Central Achievers Program.

Stroup, D., and D. Wetmore. Department of Biology and Chemistry, William Jewell College. EXPRESSION OF CYCLIN B1 IN *P53*-MUTANT U138 MG GLIOBLASTOMA CELLS AFTER EXPOSURE TO ETOPOSIDE (VP16). Glioblastoma multiforme is the most aggressive of the glioma cancers. [1] Gross pathology displays regions of necrosis and hemorrhage. [1] Microscopically, regions of pseudopalisading necrosis, pleomorphic nuclei and cells, and microvascular proliferation can be observed. [1] Genetically deletions, amplifications and point mutations have been identified. [1] If damaged DNA, in a normal cell, is discovered then *p53* regulates the level of cyclin B1 so that the initiation of mitosis cannot begin and the cell either arrests or goes into apoptosis. [3] The hypotheses in this experiment were after dosing U138 MG glioblastoma cells with VP16, cyclin B1 expression will increase in the presence of caffeine, and cyclin B1 expression will decrease in the presence of genistein. The cells were rehydrated, and the primary monoclonal cyclin B1 antibody was applied to the cells. After incubation with the primary antibody, the cells were reacted with a streptavidin-linked secondary antibody that will allow time for chromatin formation at the site of cyclin B1 expression. The cells were then counterstained with hematoxylin and sealed under a coverslip with aqueous mounting medium. A cellular histogram of cyclin B1 will then be analyzed by microscopy.

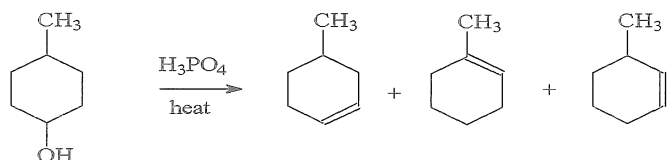
Walters, D.S. and L.A. Wetmore. Department of Biology and Chemistry, William Jewell College. A DYSFUNCTIONAL *G₂* CELL CYCLE CHECKPOINT PATHWAY IN *p53*-MUTANT GLIOMA CELLS. Glioblastoma tumors are aggressive brain tumors which are inoperable and resistant to chemotherapy and radiation. Cell cycle checkpoints monitor DNA integrity and control cell cycle division. Because these tumors are resistant to traditional cancer treatments that target DNA, investigation of the cell cycle checkpoints in glioblastoma may reveal more effective methods of treatment. In this research, the *G₂* cell cycle checkpoint in two *p53* -mutant glioma cell lines, U138MG and U373MG, was analyzed by treatment with one or more of the following reagents: etoposide, a topoisomerase II inhibitor; genistein, a topoisomerase II and tyrosine kinase inhibitor known to activate a *G₂* blockade via the ATM pathway; and caffeine, a *G₂* cell cycle checkpoint ATM pathway inhibitor. Some glioblastoma cells are hyperploidy, meaning they contain excessive amounts of DNA. When dosed with a combination of the above reagents, U138 display a decreased hyperploidy population of

cells, while U373 display an increase. These results confirm a dysfunction in the G₂/M cell cycle checkpoint. Based on these results, cyclin B levels, the cyclin which regulates entrance into mitosis, requires further study in U138 and U373.

Wieberg, C.G.,¹ R.E.Kissell Jr.,¹ L. Hansen,² and J. Beringer.² ¹Division of Agriculture, Natural Sciences and Mathematics, Lincoln University. ²Missouri Department of Conservation. SPATIAL AND TEMPORAL RELATIONSHIPS OF WHITE-TAILED DEER ANTLER CHARACTERISTICS IN MISSOURI. How antler size varies across Missouri is unknown. In addition, the effect of the environment on antler size has received limited attention and has not been examined in the Midwest. Our objectives were to 1) determine geographic patterns of antler size across Missouri and 2) determine spatio-temporal changes of antler characteristics in Missouri between the periods 1951-1970 and 1997-2001. Antler size, as indicated by beam circumference (mm) and the number of points, was collected at county check-stations by MDC personnel and volunteers during 2 time periods, 1951 to 1970 and 1997 to 2001. Mean circumference and mean number of points by county and physiographic region were determined for 1.5-year-old deer. Regression of antler characteristics and latitude/longitude indicated latitude was important ($p < 0.0001$). Geographic distribution of antler characteristics has changed over time. Variation of antler size became less over time and indicated a northwest to southeast trend. We will discuss possible explanations of our findings.

Chemistry Section

Evans, A.E., L.E. Hart, S.E. Lilley, C.A., Starkey, R.D. Toliver, B.J. Wiskur, and J.C. Easdon. Department of Chemistry, College of the Ozarks. DEHYDRATION OF METHYL-CYCLOHEXANOLS. A common undergraduate experiment is to determine the mechanism of dehydration of methylcyclohexanols. The product ratios from 2-methylcyclohexanol changes during the reaction. This so called "Evelyn effect" has only been reported for the 2- isomer and was used to suggest both E1 and E2 mechanisms are involved. Alternatively, regioselectivity and kinetic data were used to support an E2-like mechanism that involved a bridging ion. Our results (GC/MS) show that the "Evelyn effect" exists for the 4-methylcyclohexanol as well. This, and our detection of rearranged products (equation 2) suggest that the mechanism could involve either 1) elimination followed by addition of water and then another elimination, 2) elimination followed by protonation to form a different carbocation which then eliminates, or 3) a mechanism that is more "E2-like" for the stereoisomer which readily exists in an anti-periplanar conformation while the other stereoisomer reacts by a more "E1-like" mechanism.



Hlatshwayo, M. and J. Bennett. Department of Chemistry, Drury University. EVIDENCE OF A HOMOSERINE ESTER AS A BY-PRODUCT OF PROTEIN CLEAVAGE BY CYANOGEN BROMIDE. Cyanogen bromide is a reagent commonly used in protein sequencing because it specifically cleaves at the C-terminal side of methionine residues. In addition to the generally accepted products of this reaction, recent work suggests that another side reaction may be occurring. This proposed reaction involves the displacement of methyl thiocyanate by the amide carbonyl oxygen from the adjacent N-terminal amino acid. The resulting product would yield an uncleaved protein containing a homoserine ester. In order to prove that this proposed mechanism occurs, a synthetic peptide containing normethionine, rather than methionine, is currently being studied. The expected product from cyanogen bromide treatment of this peptide should occur via the newly proposed mechanism due to ring size constraints. The crude product mix of this reaction will be purified by HPLC and peak-containing fractions will be submitted for mass spectrometric analysis at the University of California, Riverside. Ultimately, after the existence of this undesirable side reaction has been proven, alternative reaction conditions will be developed to limit its occurrence.

Kent, B., C. Nelson, E. Stone, M. Hlatshwayo, and J. Bennett. Department of Chemistry, Drury University. DEVELOPMENT OF A "GREEN" ALDOL CONDENSATION PROJECT FOR ORGANIC CHEMISTRY LABORATORY. The goal of this study was to take current, cutting-edge research and implement it as a laboratory project for sophomore-level organic chemistry students. Biological catalysis is currently being developed to facilitate many classic organic reactions to make them environmentally friendlier than traditional catalysts. A recent communication from the Journal of Organic Chemistry describing an asymmetric, biologically-catalyzed aldol reaction was used as the basis for this study. The experiment involved the use of L-proline, a naturally occurring amino acid, to catalyze the transformation of three equivalents of acetaldehyde into 5-hydroxy-2-hexenal, a macrolide antibiotic precursor. The reaction yielded a fairly high enantiomeric excess of the (S)-stereoisomer under the conditions used. A variety of common techniques were performed to purify and analyze samples, including thin layer chromatography, ultraviolet-visible spectroscopy, infrared spectroscopy, nuclear magnetic resonance, polarimetry, and flash chromatography. The project designed could be performed successfully in two lab periods using all, or a subset, of the aforementioned techniques. Adaptation of this scheme to a more advanced organic course could be achieved by incorporating gas chromatography-mass spectrometry and more extensive nuclear magnetic resonance analyses.

Konneman, H.A. and L.A. Wetmore. Department of Chemistry, William Jewell College. DETECTION OF DNA-ADDUCT FORMATION BY EXPOXY DENTAL MONOMERS USING HPLC. Many dental resin monomers contain epoxide functional groups that can form DNA adducts. We are interested in assessing the ability of the dental resin monomer 3',4'-epoxycyclohexanemethyl-3,4-epoxycyclohexane carboxylate (UVR-6105) to form a DNA adduct. Previous studies indicate that extensive DNA damage occurs in L929 mouse fibro-

last cells after exposure to UVR-6105. It is thus hypothesized that UVR-6105 forms DNA adducts in these cells. This hypothesis is tested by incubating deoxyribonucleotides and DNA with UVR-6105 then digesting with phosphodiesterase and phosphatase. The resulting nucleosides are analyzed using an adapted HPLC method utilizing solid phase extraction on a C18 cartridge followed by reversed-phase chromatography with an organic/potassium phosphate buffer mobile phase. Eluant peaks are detected by UV absorption at 262 nm.

Pettegrew, B. and J. Gordon. *Division of Science and Mathematics, Central Methodist College.* THE DETERMINATION OF SULFATE AND NITRATE IN PRECIPITATION BY ION-EXCHANGE HPLC WITH INDIRECT DETECTION. The purpose of this study was to use ion-exchange chromatography to determine the anion species present in precipitation, both rain and snow. The amounts of sulfate and nitrate were of particular interest because they are partially responsible for the acidic character of precipitation. The mobile phase was modified with potassium hydrogen phthalate (KHP) that strongly absorbed at the detection wavelength of 260 nm. Upon elution of the nonabsorbing anion species, the displacement of the KHP caused a decrease in absorbance and a negative detection peak. After concentrating the precipitation samples, several anions including sulfate, nitrate, and chloride were easily detected. The amounts of nitrate and sulfate were determined to be 1.9 ppm and 3.8 ppm, respectively.

Robinson, K. and J. Grant. *The Hoffman Department of Chemistry, Drury University,* STANDARDS FOR pH MEASUREMENTS OF MOBS IN ISOTONIC SALINE MEDIA OF IONIC STRENGTH. The pH measurements of blood plasma, cerebrospinal fluids, and other clinical media, at an ionic strength $I=0.16 \text{ mol}\cdot\text{kg}^{-1}$ require primary buffer reference standards for the control of pH in the region close to the pH of blood serum. The buffer compound used was 4-[N-morpholino]butanesulfonic acid (MOBS). In order to achieve this objective, the electromotive-force measurements have been performed at temperatures between 5 to 55°C for (a) the determination of the values of pK_2 (second dissociation constant of MOBS), (b) the evaluation of pH values for six dilute buffer solutions in which NaCl has been added in amounts sufficient to raise the ionic strengths to $0.16 \text{ mol}\cdot\text{kg}^{-1}$, (c) confirmation of results of pH by calculation of liquid junction potentials, and (d) recommendation of standard pH values for four useful reference standard solutions at ionic strengths near those of blood plasma from 5 to 55°C. The results will be compared with those of similar systems and application to clinical diagnosis will be discussed.

Sigwing, A.L., E. Ilkowska, and J.F. Gaillard. *Department of Civil Engineering, Northwestern University.* METAL MICROBE INTERACTIONS: THE OXIDATION OF MANGANESE BY *LEPTOTHRIX DISCOPHORA SP-6*. The manganese oxidizing activity of *Leptothrix discophora* is possibly the best characterized example of a biologically mediated oxidation. However, even after a century of study, the mechanisms of Mn(II) oxidation and the biological functions it serves remain enigmatic. The goal of our studies was to understand the molecular mechanism of the redox process occurring in the natural

environment. Several analytical (atomic absorption spectrometry) as well as spectroscopic (UV-Vis spectrophotometry, EPR) methods have been applied to study the mechanism of the oxidation process of Mn(II) by an unknown factor produced during the microbial growth. In our experiments we checked the whole cells, unfiltered and filtered media towards ability to oxidize Mn(II). Also various types of buffers and carbon sources have been checked in order to avoid the possible subsequent reaction between them and the potential product. It was found that all mentioned above solutions were able to oxidize manganese. It has been also noticed that media with the whole cells are more active than the cell-free supernatant. The detailed concentration dependence as a function of time was performed using flame AA spectrometry. It has been observed that as the concentration of manganese in solution increases (above $200\mu\text{M}$) the oxidation ability of the supernatant decreases. It is assumed that the concentration of oxygen in the solution may play a key role in the microbial oxidation of Mn(II). A significant Mn(II) concentration decrease during the reaction may suggest an enzymatic or auto-catalytic type of mechanism.

Wigton, E., K. G. High, B.D. Wing, and M.-T. Tran *Drury University* AN NMR STUDY OF THE INTERACTIONS OF VARIOUS SUGARS WITH THE DIPEPTIDE CARNOSINE, The interactions of sugars with peptide and protein systems has attracted much interest recently. The understanding of such interactions can say much about the effect of elevated sugar in humans. In our studies, 300 MHz proton, 75 MHz Carbon-13, COSY, and HETCOR NMR techniques were used to study the dipeptide carnosine and sugars such as α -glucose. Various samples of carnosine and glucose or galactose were exposed to thermal conditions (60°C) in phosphate buffered aqueous media and unbuffered deuterated water. Under the conditions of our study, there is no evidence of reaction between the dipeptide and the sugar even after four days. Also, the dipeptide itself does not hydrolyze. Indeed, the only apparent interaction between carnosine and glucose under the conditions of this study is a shift in the equilibrium between the alpha and beta forms of the sugar.

Geology Section

Denzer, J. and J. P. Hogan. *Department of Geology and Geophysics, University of Missouri-Rolla.* CRYSTALLIZATION CONDITIONS OF A RHYOLITE DIKE, WICHITA MOUNTAINS, OK. Temperature and pressure for crystallization of a rhyolite dike were estimated from a petrologic study and phase relationships in the $\text{SiO}_2\text{-NaAl}_3\text{Si}_3\text{O}_8\text{-KAl}_3\text{Si}_3\text{O}_8\text{-H}_2\text{O}$ system (Tuttle and Bowen, 1958). Digital images of rock slabs were analyzed to determine proportions of matrix and quartz and alkali feldspar phenocrysts. The major element composition of the dike constrains the bulk composition of the magma. An equilibrium triangle in the phase diagram was constructed using the lever rule. The proportions of fine grained matrix (quenched melt) and phenocrysts determine the length of the lever. The lever pivots on the bulk composition and must intersect the back leg of the triangle at a point fixed by the relative proportion of quartz and feldspar phenocrysts. The presence of quartz and feldspar phe-

nocysts, as well as miarolitic cavities, requires the melt composition (the opposing end of the lever) to lie on the quartz- feldspar boundary line. The position of the boundary line varies with pressure. The calculated melt composition coincides with the 1.0 kb boundary line at $\sim 720^{\circ}\text{C}$ which represents crystallization conditions in the magma chamber prior to emplacement.

Grand, R. Southwest Missouri State University. FOUR URBAN SPRINGS IN SOUTHERN SPRINGFIELD, MISSOURI WERE ANALYZED AND COMPARED. The springs' alkalinity, conductivity and pH were monitored over several months. The presence of optical brighteners was also tested. The results were compared among the springs to find correlations between the variables. The conclusions are used to correlate the springs to one another, without the use of expensive dye-tracing or other techniques.

Lawrence, Z., S. Cardimona, and J. P. Hogan. Department of Geology and Geophysics, University of Missouri-Rolla. SHALLOW SEISMIC REFLECTION STUDY OF DEFORMED ORDOVICIAN STRATA, TEXAS CO. MO. Folded sandstone layers of the Roubidoux Fm. are well exposed along a 7 km stretch of Highway 63 in Texas CO, MO. The origin of this deformation remains controversial. Are the folds related to karsting and collapse of underlying caverns or an episode of compressional tectonism? To resolve this question a shallow seismic reflection experiment was performed to try and image the nature and orientation of the underlying dolomites of the Gasconade Fm. A twelve channel seismograph, with 40 Hz geophones at 5 ft. intervals and a sledgehammer source were used to produce the seismic records. Standard processing procedures revealed several prominent reflectors. However, the origin of these reflectors, whether or not they represent geologic contacts or are artifacts of data collection and processing, remains ambiguous. To differentiate multiples from primary reflectors may require direct velocity measurements of sandstone and dolomite or an additional seismic reflection experiment with new acquisition parameters. At this time the origin of this deformation still remains open to debate.

Trujillo, J., and J.P. Hogan, Department of Geology and Geophysics, University of Missouri-Rolla. SEDIMENTARY STRUCTURES IN THE LUCERNE GRANITE, ME. The Lucerne pluton is predominantly comprised of a coarse-grained seriate hornblende, biotite granite with megacrystic feldspar crystals. Mafic minerals typically comprise $\sim 10\%$ of the granite. A new road cut exposes granite characterized by alternating layers of high concentrations of mafic minerals (schlieren) and high concentrations of felsic minerals. Schlieren occur at the bottom of each couplet and grade upwards to quartz and larger feldspar grains. Schlieren consists of biotite, amphibole, zircon, allanite, monazite, magnetite, and fluorite. Schlieren exhibit layering similar to cross-bedding and preserve ripple marks along their base. Individual layers coarsen upward, however the outcrop has a general trend of fining upward. The section is capped by a subhorizontal three-foot aplite dike. Sedimentary structures indicate flow segregation and gravitational settling played a role in forming these distinctive mineralogic layers within the granite. This indicates more dynamic conditions during crystallization than previously thought for granitic magma chambers, and represents an important mechanism for crystal-melt fractionation.

Physics

Crouse, W. and B. Kisker. Department of Chemistry and Physics, Northwest Missouri State University. MUSICAL ACOUSTICS OF THE TROMBONE. By measuring the Fourier frequency spectrum of a trombone differences can be seen in a number of factors which may effect this spectrum. What differences are seen between different players? How well can one player reproduce the same spectrum? What differences do different mouthpieces make in the sound produced by the trombone? It has been found that individual players can reproduce the same spectrum quite regularly. Though individual players do each produce a unique sound the differences are not very large in the spectra. The only difference observed between different mouthpieces was between metal vs. plastic.

Heavilin, B.R., and J. Findley. Department of Chemistry and Physics, Northwest Missouri State University. COEFFICIENTS OF RESTITUTION AND IMPULSE FOR BOUNCING BALLS. Does one make of golf ball bounce off of the club any faster than other makes of golf balls and if it does, what physical differences exist in the ball? Two measurements are made in answering this question. First a high-speed digital motion picture camera was used to determine the coefficient of restitution of different balls by dropping the balls from a certain height and measuring how high they bounced. Second the Force exerted on the ball during impact was measured as a function of time using a force sensor which was interfaced to a computer. The sensor could sample at up to 289,000 samples per second. The impulse to the ball could then be calculated. Other balls besides golf balls were also used for comparison.

Licate, L.A., D. Peakhart, and J. Martin. Department of Physics, Parks College of Saint Louis University, Department of Physics, Oklahoma State University. CZOCHRALSKI GROWTH AND CHARACTERIZATION OF SINGLE CRYSTAL LiF. The Czochralski technique was used to grow single-crystal lithium fluoride for use as a UV window material. In the Czochralski method a LiF seed crystal of known orientation is dipped into molten LiF and slowly drawn out, allowing the melt to crystallize on it. After cutting and polishing, two spectrometers were used to measure the absorption coefficient of the crystals over a wavelength range between 200 nm and 5000 nm. The initial crystals showed OH contamination identified by absorption peaks at 2760 nm and at 2800 nm. A plot of these peaks as a function of crystal length shows that the contamination is less at the bottom of the boule than at the seed end. By treating the growth material with HF the OH can be removed. HF will combine with OH to form a water molecule and a fluoride ion. The water molecule is removed by the vacuum system, and the fluoride becomes part of the crystal. These experiments show that by using a superior growth material and by treating the material with HF, the Czochralski method can produce crystals suitable for UV window material. This work was made possible by an NSF/REU program at Oklahoma State University.

Obajtek, R.A. Department of Physics, Parks College of Saint Louis University. THREE-STATE QUANTUM CRYPTOGRAPHY. Cryptography plays an important role in modern communication because of the necessity of security. One type of quantum cryptography scheme is essentially a Vernam cipher. It allows two parties, Alice and Bob, to share a random key without ever having met. The system also enables Alice and Bob to detect the presence of eavesdroppers. In this study, a quantum cryptography scheme using three symmetric quantum states was investigated to determine whether the three-state scheme is more secure than a system that uses only two quantum states. The two-state quantum cryptography protocol is described, then generalized to work for three quantum states. An expression for the trade-off between security and information rate is constructed for a cryptosystem based on three symmetric states. It was found that when compared to a similar trade-off for two states, the trade-off peak for three states is about 1.5 times higher. This result suggests that three-state quantum cryptography is approximately 1.5 times better than two-state quantum cryptography. This work was done in collaboration with Christopher A. Fuchs during the Summer Research Program for Minorities and Women at Lucent Technologies, Bell Labs.

Manuscript Instructions for Authors

Please read and follow these instructions for submission of an article for the Transactions of the Missouri Academy of Science. An attempt has been made to keep submission as simple and straightforward as possible.

Editorial Policy

Authors must pay \$25.00 per printed page for publication costs. Transactions publish several types of original contribution from the disciplines within the Academy: research papers, research notes, reviews, and annotated bibliographies. Manuscripts must be authored or co-authored by a member of the Academy. Each manuscript is subject to peer review. The Editor has final authority for acceptance or rejection. Manuscripts should be submitted prior to May 15 to the MAS Business Office: Missouri Academy of Science

Attn: Paula L. Macy

W.C. Morris 203

Central Missouri State University

Warrensburg, MO 64093

Materials to be Submitted

The article is to be submitted in two forms: on a microcomputer disk and as a printed hard copy. Instructions for each of these forms are described in more detail below. Most authors probably already have their article on microcomputer media in some form but we will require that it be submitted following a particular protocol.

Microcomputer Disk

Disk Requirements: Materials for publication must be submitted on a 3.5" High-Density (1.44MB capacity) floppy disk formatted for Microsoft Operating Systems (MS-DOS). Label the disk with the first Author's Name.

Text Preparation: The text material should be prepared or converted to New Times Roman (Times) or Arial font with a print of 10-point type. DO NOT underline anything, use italics if needed for scientific names or other terms in a language different from the rest of the text. DO NOT insert any codes for justification, hyphenation, line height, line centering, margins, spacing, fonts, page centering, page numbering, suppression, tabs, or other special features. YOU MAY use subscripts, superscripts, and any of the available graphic characters available for the fonts used. USE ONLY SINGLE TABS. YOU MAY also use the Symbolic font if needed for special characters. All material should be in black on white, no color material permitted.

DO NOT try to create your own approximation of hanging indent formatting for the literature cited or references section by using returns and tabs for the lines. Acceptable software has an automatic hanging indent feature, which should be used with the built in auto wrap feature of word processing. Avoid linked or embedded objects, images, and other advanced word processing capabilities, we will take care of this in final processing e.g. placing figures and tables in text at appropriate locations.

Graphics: Tables should be constructed using single tabs between columns and returns at end of sentence. Number tables consecutively and provide a short title at the top of each page. Keep in mind that the larger format of the Transactions will allow larger graphs and figures. Because there will be two columns per page, graphics can be put in a single column or can be across two columns up to the size of the page. We anticipate having scanned images submitted for publication and they must be of appropriate size when saved to the disk. Please contact the editor if you have questions, email at <jfbelshe@iland.net>. Scan images at 300dpi minimum and grayscale images should be scanned at 450-dpi minimum.

Saving the File to Disk: The text and all printed material in the file should be saved to the disk as a WordPerfect or Word (5.0 or higher) in SINGLE LINE SPACING. In addition, please save the file as a RTF (Rich Text Format) file with RTF added to the file name. I recognize that articles may have been prepared on Macintosh systems, but the files can be saved to an PC formatted disk as a file appropriate for the system named above. Use the SAVE AS command and save as requested.

Printed Hard Copy: Please submit four (4) copies of the manuscript DOUBLE-SPACED, on one side of standard sized paper. These hard copies should correctly show how you want to represent any special characters, equations, tables, etc. The manuscript is to be assembled in the following order: Title, Author(s) name(s) and affiliation, Abstract, Key words, Text, Acknowledgements, Literature cited, Tables, Figure legends, Figures. Number pages. Use the common and binomial Latin name of an organism when first mentioned. Subsequently the genus or common name may be used. Names of taxa should be underlined. The text must match the document file text exactly. Distinguish between similar-looking but different symbols such as the letter "x", a multiplication sign, and a Greek Chi. Similar problems occur with minus signs, hyphens, and dashes; there are different symbols for each of these.

Please provide the names of two or three possible reviewers in your cover letter.

Where to Send Materials: Send all materials to: Missouri Academy of Science, W. C. Morris 203, Central Missouri State University, Warrensburg, MO 64093.

Missouri Academy of Science
Attn: Paula Macy
W.C. Morris 203
Central Missouri State University
Warrensburg, MO 64093

CHANGE SERVICE REQUESTED

PAULA L MACY
MISSOURI ACADEMY OF SCIENCE
CENTRAL MO STATE UNIVERISTY
GRINSTEAD 245B
WARRENSBURG MO 64093-5053